Analyzing the risk factors influencing surgical site infections: the site of environmental factors

Physician extenders on surgical services: a systematic review

Comparison of outcomes of root replacement procedures and supracoronary techniques for surgical repair of acute aortic dissection

A comparison of revisional and primary bariatric surgery
UNCOVERING HIDRADENITIS SUPPURATIVA

Dr. Shear, Dr. Tran and Dr. George discuss Hidradenitis Suppurativa.

Q. WHAT IS HS?
A. Hidradenitis Suppurativa (HS) is a chronic, painful, inflammatory skin disease which affects 1-4% of the general adult population. It is characterized by boils usually occurring where certain sweat glands are located, such as under the breasts, buttocks and inner thighs. The boils can develop and connect, forming draining sinuses which discharge foul-smelling pus.

Q. WHAT CAUSES HS?
A. The cause of HS is unclear. It is thought that certain genetic markers and defects within hair follicles are at the root of the disease. Risk factors include smoking and obesity. About one-third of patients report a family history of HS. HS has been reported to co-occur with several comorbid conditions—mostly, inflammatory bowel disease.

Q. HOW DOES HS IMPACT QUALITY OF LIFE?
A. HS is often undiagnosed or misdiagnosed. It interferes with social interactions, job performance and intimate relationships—often leading to isolation. It is painful and causes embarrassment.

Q. DO PEOPLE SUFFERING FROM HS GO TO THE ER FOR TREATMENT?
A. People with HS come to the emergency room in severe pain and discomfort requiring assistance with the draining of the boils during a flare-up. It’s not unusual for patients to go home undiagnosed.

Q. IS THERE A CURE FOR HS?
A. There is currently no cure for HS. Early diagnosis and proper management is important for a patient’s quality of life. The first step for those with HS is to speak to their dermatologist to get an accurate diagnosis.

Q. HOW CAN HS BE TREATED?
A. Medical treatments for HS have included antibacterial washes, topical clindamycin, various systemic antibiotics, hormonal therapies, systemic retinoids, laser treatment, intralesional steroid injections and biologics. Surgical de-roofing or wide excision procedures have long been the definitive treatment for severe HS. There is no guarantee that HS will not recur in the previously excised areas.

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Surgical innovation is harder than it looks

The views expressed in this editorial are those of the author and do not necessarily reflect the position of the publisher.

A recent issue of *Nature* lamented about the dearth of surgical innovation.¹ “Innovation” is just one of many new catch phrases invading medicine; it has become a hotter phrase than “knowledge translation.” It just sounds so futuristic! It also seems to be applicable across community and academic lines if promoted properly. There are other new buzzwords populating news releases on new opportunities. “Disruptive research” is another commonly used phrase. But almost nothing in medicine is disruptive, contrary to the news releases. New scalpels and laser-guided surgery are not disruptive — they are improvements to older concepts. Similarly, new Global Positioning System technology is not really disrupting the automobile industry; rather, self-driving cars will be disruptive, as they will bring new models of income and potentially free time for other tasks while driving. Hacking Health initiatives are also timely and mantra-like. But products of health hacking are not taking over my operating room and disrupting my practice. So, we are left with surgical innovation as a real goal for surgeons despite a problem with its reported dearth.

Surgeons think of themselves as innovators and great thinkers — so why is it hard to imagine or realize new surgical procedures and techniques? Actually, there are many reasons. As pointed out by the editorial in *Nature*,¹ surgeon-driven grants have decreased, as surgeons apply for fewer funding opportunities. Even though surgical departments value research, individual surgeons feel it is not their role; clinical duties outstrip research desire and, not surprisingly, less output in terms of papers and patents comes from surgical fields. The emergence of alternate science avenues for surgeons has pulled the residents and recent graduates away from core surgical principles. Epidemiology, surgical teaching and simulation research have attracted surgeons less inclined to deal with preclinical modelling. Those older disciplines are seen to be competing in an evermore difficult funding environment. This difficulty is not a perceived problem. Hu and colleagues² looked at National Institutes of Health (NIH) funding for surgical research over a decade ending in 2013. There were fewer surgical grants that underwent review: from 613 down to 512. Additionally, NIH funding fell 19.1% from $270 million to $219 million. Funding for research projects underwent the largest decrease (~38%), including a 39% decrease in R01 awards — theoretically the grant that promotes and encourages individual surgical researchers. Similar results for career awards have been seen for young surgeons (K-award programs).³ It is hard to determine if the same trends are occurring in Canada because the data are not readily available, but it is easy to see how it might be true in the institutions I have visited and where I have worked.

We need to make research and bringing ideas to fruition both easier and more gratifying. The perception that it is too hard to do scientific research means that we need to change the approach to education and execution. The Science of Team Science continues to make inroads and may allow surgeon scientists to contribute to overarching research aims. Also, the education of surgeons in an entrepreneur stream would help the innovators visualize positive outcomes. The startup milieu, though not any easier than traditional research, may appeal to clinical device developers and bring the creative cycle back to the surgeon or surgeon scientist–engineer pairings. That would be disruptive — at least of the current trends in surgeon engagement.

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**Competing interests:** E.J. Harvey is the Chief Medical Officer of Greybox Healthcare (Montreal) and Chairman of the Board of NXT-Sens Inc. (Montreal).

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Innover en chirurgie, plus difficile qu’il n’y paraît

Les opinions exprimées dans cet éditorial sont celles de l’auteur et ne représentent pas nécessairement celles de l’éditeur.

Dans un récent numéro de la revue Nature, on déplorait la pénurie d’innovation en chirurgie. L’« innovation » n’est qu’une des nombreuses expressions à la mode qui envahissent la médecine; elle a même supplanté le « transfert des connaissances ». En plus de ses échos futuristes, le mot semble vouloir lancer des ponts entre les milieux communautaires et universitaires, à condition de promouvoir la notion adéquatement. D’autres nouveaux termes émaillent aussi les communiqués de presse qui annoncent des découvertes, comme les fameuses technologies ou innovations dites « de rupture avec les tendances actuelles » (disruptive research). Heureusement, contrairement à ce qu’affirment les communiqués de presse, pour ainsi dire rien en médecine ne « casse » quoi que ce soit. En effet, les nouveaux scalpels ou la chirurgie guidée par laser ne cassent rien — ce ne sont que des améliorations à des dispositifs existants. De même, la nouvelle technologie GPS (global positioning system) ne perturbe pas l’industrie d’automobile; par contre, les voitures autonomes cassent le moule en proposant de nouveaux modèles de revenus et en libérant du temps pour d’autres tâches pendant les déplacements. Les initiatives de Hacking Health (activités de remue-ménages qui permettent de briser les barrières à l’innovation) deviennent également comme des mantras et sont fort bienvenues. Mais le fruit de telles activités ne prend pas le contrôle du bloc opératoire et ne perturbe pas ma pratique. Donc, l’innovation en chirurgie demeure un objectif réel pour les chirurgiens malgré la pénurie apparente.

Les chirurgiens se perçoivent comme des innovateurs et de grands penseurs — alors pourquoi donc est-ce si difficile d’imaginer ou de réaliser de nouvelles interventions et techniques chirurgicales? En fait, il y a plusieurs raisons à cela. Comme l’expliquait l’éditorial de la revue Nature1, si les bourses de recherche accordées aux chirurgiens-chercheurs ont diminué, c’est que les chirurgiens en demandent peu. Même si les services de chirurgie valorisent la recherche, à l’échelle des individus, les chirurgiens estiment que ce n’est pas un rôle qui leur revient; la lourdeur de leur fardeau de cliniciens éteint leur désir de faire de la recherche et on ne sera pas surpris qu’il y ait moins de publications et de brevets émanant du champ de la chirurgie. L’émergence de nouvelles avenues scientifiques pour la chirurgie a toutefois attiré les résidents et les récents diplômés hors des sentiers habituels de la chirurgie. La recherche en épidémiologie, en didactique et en simulation a séduit des chirurgiens qui sont peu attirés par la modélisation préclinique. On a l’impression que ces disciplines plus anciennes sont aux prises avec un environnement où l’accès au financement est de plus en plus difficile. Cette impression est une réalité : Hu et coll.2 ont analysé le financement accordé à la recherche en chirurgie par les National Institutes of Health (NIH) des États-Unis entre 2003 et 2013. Il appert que le nombre de demandes de subvention étudiées est passé de 613 à 512 au cours de cette période. Et le financement des NIH a aussi diminué de 19,1 %, passant de 270 à 219 millions de dollars. C’est le financement des projets de recherche qui a subi la baisse la plus importante (–38 %), y compris des baisses de 39 % touchant les bourses destinées aux résidents de première année — en théorie, le type de bourses qui encourage et stimule la recherche individuelle. On a observé un phénomène similaire pour les bourses de développement de carrière (Career Development [K] Awards) à l’intention des jeunes chirurgiens.3 Il est difficile de déterminer si les mêmes tendances s’observent au Canada parce que les données sont difficilement accessibles, mais il est facile de voir comment cela pourrait se manifester dans les établissements que j’ai visités et où j’ai travaillé.

Nous devons faciliter et valoriser la recherche et l’application des fruits de la recherche. Si nous percevons la recherche scientifique comme quelque chose de difficile, c’est donc qu’il faut modifier notre approche à la formation des chercheurs et notre façon de réaliser des projets scientifiques. La recherche intégrative (science of team science) continue de faire des percées et pourrait permettre aux chirurgiens-chercheurs de contribuer à l’atteinte d’objectifs scientifiques fondamentaux. Également, la formation des chirurgiens dans une catégorie entrepreneuriale aiderait les innovateurs à visualiser leurs résultats. Le milieu des entreprises en démarrage, même s’il ne s’agit pas à proprement parler d’une avenue de recherche plus facile que les autres, pourrait attirer des inventeurs et donner un nouvel élan créatif au jumelage chirurgien/ingénieur ou chirurgien-chercheur/ingénieur. Cela créerait à tout le moins une rupture avec les tendances actuelles pour ce qui est de l’engagement des chirurgiens.

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Références
Vascular control during laparoscopic kidney donation

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SUMMARY

Laparoscopic donor nephrectomy (LDN) is the gold standard for kidney donation. Recent literature has led to considerable debate regarding the safest route to provide vascular control during this procedure. The most common devices used for vascular control during LDN are staplers and surgical clips. Opinions regarding the safety of these devices vary, as both are prone to dysfunction. Certain clips have already been contraindicated for use on the donor artery owing to reports of catastrophic complications of falling off. Donor safety is paramount to the continued success of renal transplantation in Canada. A review of existing practice at each institution may be called for to ensure the safest standards possible are in place. An appendix to this commentary is available at canjsurg.ca.

Since the initial publication by Ratner and colleagues1 in 1995, the laparoscopic donor nephrectomy (LDN) has become the standard for living kidney donation. The minimally invasive technique is associated with improved cosmetics, decreased morbidity, a shorter length of stay and a quicker return to work, all of which have led to increased living donation rates around the globe.2 The actual operation has evolved with notable improvements in optics, surgical instrumentation and energy sources.3

In recent years, the method of vascular control of the renal vessels has come under scrutiny owing to reported catastrophic outcomes of device failures.3,4 The balance between donor safety and ensuring a sufficient vessel length for the transplantation anastomoses can be a fine line. The 2 most common modalities used to ligate and divide the artery and vein laparoscopically are surgical clips (locking and nonlocking) and staplers. Each technique comes with a risk of malfunction: clip slippage and stapler misfire, respectively.5

Surgical principles would imply that stapling is the safer of the 2 techniques, given that the staples actually transfix the vessel wall. Stapling devices allow for the division and ligation of the artery or vein in a single motion. The accepted sacrifice is the loss of a couple of millimeters of length on the graft vessel. Unlike staplers, surgical clips do not transfix the vessel wall. This leads to a risk of clip slippage, especially in a donor nephrectomy where there is a tendency to cut flush with the clip in order to facilitate longer vessel length. Several reports of donor deaths associated with locking clip slippage have led to the U.S. Food and Drug Administration placing a warning that plastic locking clips are contraindicated for use on the donor artery during nephrectomy.1

The use of staplers and clips is now commonplace throughout all surgical practices. But we must not forget that the rate of device malfunction is not trivial for either of these techniques. There is a strong suspicion that the actual incidence of stapler misfire and clip slippage is severely under-reported. Resultant hemorrhage from a poorly secured renal artery can be brisk and difficult to control even with immediate action and conversion to an open laparotomy. For this reason, there has been a trend away from
nontransfixating means to secure the renal artery (e.g., clips) and a trend toward the use of transfixating devices, such as staplers. To minimize the risk of stapler misfire, many transplant centres have now transitioned to the use of noncutting staplers.

Despite the undesired outcome of device malfunction during hilar control in LDN, there is an important difference in how malfunctions can present. A stapler misfire is an immediate, observed complication that allows for the surgeon to react to the situation, potentially by compressing or grasping the vascular stump and/or immediately converting to open surgery. Clip slippage, on the other hand, is often delayed by hours or even days. This leaves the patient and medical team unaware of the hemorrhage while the patient is in the recovery room or on the ward, leaving little hope of timely reaction and salvage.

We recently surveyed 28 kidney donor surgeons from across Canada and found that a significant proportion have experienced either clip slippage or stapler misfire during donor procedures, some of which resulted in catastrophic outcomes (Appendix 1, available at canjsurg.ca). These findings are in keeping with those of similar surveys performed in the United States and Europe. An important message that emerges from this relatively high rate of device failure, whether transfixing or not, is that all surgical devices are prone to malfunction and can lead to unwanted complications. In no other surgical population does this trepidation become more real than in live donors. This highlights the inherent risk of performing major surgery on healthy volunteers for the benefit of another patient.

Based on the findings of our survey along with information available from similar studies in the literature, we feel that it is vital that all transplant programs review their existing practices and make appropriate modifications to ensure that donor surgery is performed in accordance with the safest standards possible. The recommendations that we feel are reasonable to consider are outlined in Box 1. Furthermore, emergency simulations should be performed routinely by the transplant team of anesthesiologists, surgeons and nurses so as to minimize morbidity and mortality associated with intraoperative complications of LDN.

Although rare, hemorrhagic complications can occur from device malfunction, resulting in poor outcomes for healthy volunteers undergoing LDN. With this in mind, surgeons need to remain vigilant when choosing their technique for vascular control.

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**References**

The University of Toronto’s lasting contribution to war surgery: how Maj. L. Bruce Robertson fundamentally transformed thinking toward blood transfusion during the First World War

SUMMARY

During the Great War, Canadian military surgeons produced some of the greatest innovations to improve survival on the battlefield. Arguably, the most important was bringing blood transfusion practice close to the edge of the battlefield to resuscitate the many casualties dying of hemorrhagic shock. Dr. L. Bruce Robertson of the Canadian Army Medical Corps was the pioneering surgeon from the University of Toronto who was able to demonstrate the benefit of blood transfusions near the front line and counter the belief that saline was the resuscitation fluid of choice in military medicine. Robertson would go on to survive the Great War, but would be taken early in life by influenza. Despite his life and career being cut short, Robertson’s work is still carried on today by many military medical organizations who strive to bring blood to the wounded in austere and dangerous settings. This article has an Appendix, available at canjsurg.ca

In the spring of 1914, the prospect of a war between Great Britain and Germany loomed as a likely possibility. This possibility turned to certainty with the German invasion of Belgium. When Great Britain declared war on Germany on Aug. 4, 1914, the ramifications were felt throughout the British Empire, including in the Dominion of Canada. It was widely seen as the patriotic duty of every British subject to volunteer and support the war effort. Within Canada, Toronto was a hotbed of pro-British sentiment, and the University of Toronto’s Faculty of Medicine was no exception. By the spring of 1915, the University of Toronto had created the No. 4 Canadian General Hospital, which was a fully equipped and staffed 1040-bed hospital (see Appendix 1, available at canjsurg.ca, for a full description). In addition to this institutional contribution, many Toronto medicine alumni volunteered, including such medical luminaries as John McCrae, Frederick Banting and Norman Bethune, whose lasting accomplishments are now part of the Canadian legend. McCrae, Banting and Bethune all volunteered to serve Canada in the Great War, the latter 2 as medical students from the class of 1916.

One of the most important medical advances was made by a University of Toronto surgeon during the Great War, and this contribution to war surgery and medicine is often overlooked. Specifically, the use of transfusion of fresh whole blood for the treatment of hemorrhagic shock, as championed by...
Dr. L. Bruce Robertson is often relegated to a footnote in medical history, but this advance was pronounced “the most important medical advance to come from the First World War” by the Royal Army Medical Corps (RAMC).\(^2\) Robertson’s pioneering work in the field and his fierce advocacy for its use on the front lines continues to have ramifications both in present-day trauma centres as well as on the modern battlefield. This article will summarize his work, which has been expertly and extensively reviewed in a series of articles by Pinkerton.\(^3,4\)

Born in Toronto in 1885, Lawrence Bruce Robertson, who went by his middle name, studied medicine at the University of Toronto and graduated in 1909. He then went on to pursue a 1-year surgical internship at The Hospital for Sick Children. The next step in his studies was pivotal, as he travelled to Bellevue Hospital in New York. During his 18 months there, he trained with Dr. Edward Lindeman, who had developed a multiple syringe technique for blood transfusion.\(^5\) At this time, transfusion techniques were still in their infancy, with some advocates requiring a direct donor (artery) to recipient (vein) vascular anastomosis.\(^6\) Since then, other methods had been attempted and refined, including Lindeman’s technique. Following his stint with Lindeman in New York, Robertson then went to Boston to complete his surgical training, armed with this newly acquired familiarity with blood transfusion techniques.

Robertson returned to Toronto and took up a staff position at The Hospital for Sick Children in 1913. He continued to practise transfusion (considered a surgical procedure at the time) using a systematized approach. Indeed, after his arrival at The Hospital for Sick Children, he and his colleague Dr. W.E. Gallic began performing blood transfusions in a series of surgical patients.\(^7\) Upon the declaration of war against Germany, Robertson’s response was immediate; his commission is dated Aug. 5, 1914, the day after war was declared, and is evidence of Robertson’s patriotic fervour.

Despite his early eagerness, he was not deployed overseas until April 1915, when his unit, No. 2 Canadian Casualty Clearing Station, arrived first in England and moved on to Aire, France, in September of the same year. Almost immediately after his arrival in France, he was seconded to a British unit near Boulogne, No. 14 General Hospital, commencing Oct. 5, 1915. It was here that the impact of Robertson’s contribution became evident.

At this point, the practice of blood transfusion had been developed and gained acceptance as a life-saving intervention among the civilian American surgical community. However, it was not well received and was even denigrated within the prevailing British surgical thinking. The *British Medical Journal* had gone so far as to publish a review stating that “surgeons, we imagine, will find no good reasons … for abandoning the safe and simple method of saline injection.”\(^7^\) Thus, Robertson found himself in a unique position. As the Americans did not enter the war until April of 1917, the predominant attitude in most Allied military units was to rely on saline as a resuscitative fluid. Robertson’s familiarity with blood transfusions allowed him to be the first to demonstrate the benefits of blood transfusion on the battlefield. Indeed, one could argue that this is yet another example of a historical Canadian advantage that facilitated the confluence of ideas between the receding British Empire and the rising American superpower. By virtue of its geographic proximity to the United States and its cultural and political ties to Great Britain, Canada has been able to benefit from both societies.

In typical fashion, Robertson lost no time and performed his first blood transfusion on Oct. 30, 1915. He published a case series of 4 patients who received uncrossmatched blood transfusion as a proof of concept in 1916.\(^8\) One of the patients in this series died from what was likely an acute hemolytic reaction. Although Robertson initially argued that the risks associated with using uncrossmatched blood were outweighed by the acute need for blood transfusion in cases of hemorrhagic shock, he would later moderate his stance to recommend test injections of blood before larger volume transfusion. As the war continued, Robertson rejoined No. 2 Canadian Casualty Clearing Station, was then seconded to another British unit, and finally returned to his home unit for the remainder of his service in the war. During his time at the Western Front, Robertson treated Allied forces from the sites of several famous and horrifying battles, including Ypres and Passchendaele. Robertson continued to advocate the importance of and practise blood transfusion, publishing further papers on the subject in 1917.\(^9,11\)

One of these articles, which was published in the *British Medical Journal*, summarized a further series of 68 patients in whom blood transfusion was used.\(^10\) The effects on patient outcomes were outstanding and galvanized interest among the British medical community in blood transfusion. A commentary by Col. C. Watson on the importance of Robertson’s work accompanied the article:

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L. Bruce Robertson (centre) operating circa 1917. L. Bruce Robertson fonds, F 1374, Archives of Ontario, I0050276.

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HISTORY OF SURGERY: FIRST WORLD WAR

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years after Robertson’s transformative studies, the Canadian Forces Blood Program was created to support Canadian operations globally. One hundred years after Robertson’s work, blood transfusion was recognized as a lifesaving treatment for traumatic hemorrhage. Robertson had been overseas for only 2 years at this point, though the murderous nature of the Western Front provided him with more than enough clinical cases to argue his point. Thanks mostly to Robertson’s continued work on transfusion on the Western Front and his ongoing scholarly publications of his results, the RAMC adopted transfusion as standard practice.

In December 1917, Robertson was invalided home, bringing his wartime experience to an end. After the war ended in 1918, Robertson returned to his surgical practice at The Hospital for Sick Children and continued to practise and study blood transfusion. His life was tragically cut short 5 years later in 1923 when he died from pneumonia as a complication of influenza. He was 37 years old.

Despite his early death, Robertson’s legacy was profound. Blood transfusion for traumatic hemorrhage continued to be practised after the Great War. During the Spanish Civil War, a centralized blood transfusion service was organized under the direction of Dr. Norman Bethune, another First World War veteran and University of Toronto Medical graduate. Blood transfusion continues to be the cornerstone of modern trauma management to this day and, not surprisingly, “what is new is old, and what is old is new.” The importance of having a walking blood bank was reintroduced to the Canadian Forces Health Services in 2006 while Canada was fielding a combat hospital in Afghanistan. Recently, a permanent Canadian Forces Blood Program was created to support Canadian operations globally. One hundred years after Robertson’s transformative studies, the importance of blood products for resuscitation close to the battlefield is still paramount, and Canada is still making contributions to the study of hemorrhagic shock and resuscitation.

During the First World War, the University of Toronto’s Faculty of Medicine and Department of Surgery contributed both institutionally and individually to the war effort. One of those individuals, L. Bruce Robertson, almost single-handedly changed the management of combat casualties by demonstrating the efficacy of blood transfusion for resuscitation of shock due to hemorrhage. He was a dutiful soldier, a skilled surgeon and a determined scientist. Let us remember him.

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Analyzing the risk factors influencing surgical site infections: the site of environmental factors

Background: Addressing surgical site infection (SSI) is accomplished, in part, through studies that attempt to clarify the nature of many essential factors in the control of SSI. We sought to examine the link between multiple risk factors, including environmental factors, and SSI for prevention management.

Methods: We conducted a longitudinal prospective study to identify SSIs in all patients who underwent interventions in 2014 in 8 selected hospitals on the Mediterranean coast of Spain. Risk factors related to the operating theatre included level of fungi and bacterial contamination, temperature and humidity, air renewal and differential air pressure. Patient-related variables included age, sex, comorbidity, nutrition level and transfusion. Other factors were antibiotic prophylaxis, electric versus manual shaving, American Society of Anaesthesiologists physical status classification, type of intervention, duration of the intervention and preoperative stay.

Results: Superficial SSI was most often associated with environmental factors, such as environmental contamination by fungi (from 2 colony-forming units) and bacteria as well as surface contamination. When there was no contamination in the operating room, no SSI was detected. Factors that determined deep and organ/space SSI were more often associated with patient characteristics (age, sex, transfusion, nasogastric feeding and nutrition, as measured by the level of albumin in the blood), type of intervention and preoperative stay. Antibiotic prophylaxis and shaving with electric razor were protective factors for both types of infection, whereas the duration of the intervention and the classification of the intervention as “dirty” were shared risk factors.

Conclusion: Our results suggest the importance of environmental and surface contamination control to prevent SSI.
M ost authors accept that surgical site infection (SSI) is one of the worst complications that a patient can experience after an intervention. Many important aspects are affected by these infections, including mortality, morbidity, changes in prostheses, functional dependence and lawsuits as well as the associated costs of a prolonged hospital stay and increased total health care, social and labour costs. A multitude of studies worldwide focus on this issue from different scientific perspectives, refining the definitions of SSI parameters and risk factors as well as increasing our knowledge of what factors are important contributors to SSIs and how to control them at a clinical level.1–3

In the past few years, important advances have been achieved in the field that may have had an impact on the reduction of SSIs.4 These include more effective surgical sterilization procedures, laminar flow, high-efficiency particulate absorbing (HEPA) filters, ultraviolet radiation, air renewal, humidity control, differential temperature and air pressure, particle count, surface colony count and antibiotic prophylaxis.5–8 However, other factors, such as decreased length of hospital stay, and more aggressive interventions performed on patients with worse clinical conditions, probably contribute to an increased incidence of SSIs.

The influence of all these factors is not clear given that, to our knowledge, no studies have examined the link between multiple factors, especially environmental control, and SSI. The goal of pursuing more effective systems of SSI vigilance and control is accomplished, in part, through studies such as this one, which attempt (within the current hospital dynamic) to clarify the nature of many essential aspects in the control of SSI. The main objective of our study was to analyze the relative importance of factors associated with the operating theatre and environmental biosecurity as well as patient-related factors that contribute to the incidence of superficial, deep and organ SPACE SSIs.

METHODS

The study was carried out in 8 hospitals of similar size (350–600 beds) on the Mediterranean coast of Spain. These hospitals serve a population of about 2 million people with a Mediterranean diet and lifestyle. In addition, to be included in our study, hospitals had to be public, use similar software and have had an almost identical incidence of SSIs during the previous year (2%–3%).

The study was an epidemiologic, longitudinal, prospective study carried out over the course of 1 year (2014). Services and pathologies studied were cardiac surgery, vascular surgery, general surgery, digestive surgery, neurosurgery, thoracic surgery, trauma surgery and orthopedic surgery. Patients were classified as cases (SSI) or controls (no SSI).

To be included in the study, patients had to have undergone an intervention in an operating room with laminar flow and had to have been admitted to hospital in 2014. We excluded those who were operated on in outpatient services or the short-stay surgical unit, or in an operating theatre without laminar flow.

Our institutional review boards approved the study, and we obtained informed consent from all participants.

All patients had surgery in operating rooms with HEPA filters with minimum efficiency reporting values (MERV) and laminar flow (unidirectional air moving at a steady speed along parallel lines). We reviewed the conditions of the operating room according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards on a weekly basis.9

For the definition and classification of SSI, we strictly followed the criteria set out by the Centers for Disease Control in 1999. We classified the events as superficial or deep and organ SPACE SSIs.10

In each hospital, a selected surgeon and 1 of 2 trained nurse epidemiologists inspected all patients and evaluated the wounds daily during the hospital stay; staff differed in each hospital. They were blind to other patient characteristics. All patients were prospectively followed up, either in hospital or as an outpatient, for 30 days after surgery for the development of an SSI or other postoperative complications. Follow-up visits occurred at 15 and 30 days after the intervention in all patients, and a single team at each hospital conducted all the follow-up visits in order to avoid use of different SSI assessment criteria.

Variables associated with the operating theatre were environment factors. For example, ventilation and laminar flow (unidirectional air moving at a steady speed along parallel lines). We reviewed the conditions of the operating room according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards on a weekly basis.9

For the definition and classification of SSI, we strictly followed the criteria set out by the Centers for Disease Control in 1999. We classified the events as superficial or deep and organ SPACE SSIs.10

Variables associated with the operation and recorded during each surgery were prophylaxis (appropriate antibiotic prophylaxis was defined as correct antibiotic, dosage and time of administration); depilation (electric shaving vs. manual razor); American Society of Anaesthesiologists (ASA) class;11 type of intervention according to US National Research Council group in 1964 (clean, clean–contaminated, contaminated, dirty);1 and duration of intervention.

Variables associated with the operation and recorded during each surgery were prophylaxis (appropriate antibiotic prophylaxis was defined as correct antibiotic, dosage and time of administration); depilation (electric shaving vs. manual razor); American Society of Anaesthesiologists (ASA) class;11 type of intervention according to US National Research Council group in 1964 (clean, clean–contaminated, contaminated, dirty);1 and duration of intervention.

Environmental controls (fungi and bacteria) were car-
were performed by extraction of 1 m$^3$ of air in each sample, aspired for 10 min and resulting in an expression of CFU/1000 L. The extraction ratio was approximately 1 m$^3$ per 100 of circulating air.

The contact pressure method was used to carry out surface sampling in the area near the foot of the operating table at the time of the surgery, and it was performed with 2 different samples — 1 for fungi (agar extract with chloramphenicol) and 1 for bacteria — using one-plate Rodac contact plates (size 60 × 60 mm$^2$) per sample. The total fungal concentration was determined after 72–120 h of incubation at 37°C, and all were identified at a species level based on macroscopic and microscopic morphology. Data from the operating room were gathered in the middle of every intervention (1 environmental and 2 surface samples). All samples were identified with a code and cultured in the microbiology service, which is accredited by a national accreditation organism in all the hospitals. We used the Velocicalc Plus tool (model 8386A, TSI Inc.) for the other parameters (air temperature, air velocity, pressure and relative humidity).

**Statistical analysis**

Statistical analysis was performed using SPSS software version 16.0 (SPSS Inc.). We tested the univariate association between each independent factor and SSI using the Student $t$ test for continuous variables and the $\chi^2$ test for categorical variables. Results are expressed as means ± standard deviation, and we considered results to be significant at $p < 0.05$. To test the independence of the risk factors for SSI, the significant variables in the univariate analyses were entered into a multiple logistic regression model with likelihood ratio forward selection. We then obtained the relative risk (RR) and the 95% confidence intervals (CI).

**RESULTS**

The total study sample comprised 18 910 patients, 1267 of whom experienced an SSI, for a total incidence of 6.7%.

Table 1 shows the association between SSI and the type of intervention. The incidence of SSI was 2.1% for a clean intervention, 5.1% for a clean–contaminated intervention, 12.9% for a contaminated intervention and 21.7% for a dirty intervention ($p < 0.001$).

Table 2 shows the risk of SSI associated with the ASA class. The rates were 2.7% for ASA class 1, 6.7% for class 2, 9.1% for class 3, 16.4% for class 4 and 19.9% for class 5. These differences were also significant ($p = 0.001$).

A contrast of averages was carried out (Table 3) and analyzed using the Student $t$ test, and we found significant differences with regard to the appearance of an SSI in association with the following factors: surface contamination of fungi and bacteria, environmental contamination of fungi and bacteria, temperature, humidity, air renewal, age and comorbidity of the patient, duration of the intervention, nasogastric tube, serum albumin and immunosuppression. The differential pressure in the operating room was not found to be a significant factor. The SSI rate was minimal (0.34%) in the absence of CFU, environmental, or surface contamination and when surgery was not considered dirty owing to bacteria or fungi.

**Table 1. Rate of surgical site infection by intervention type**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Clean (no. %)†</th>
<th>Clean–contaminated (no. %)†</th>
<th>Contaminated (no. %)</th>
<th>Dirty (no. %)</th>
<th>Total (no. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SSI</td>
<td>6072 (31.68)</td>
<td>7677 (40.05)</td>
<td>2745 (14.32)</td>
<td>1149 (5.99)</td>
<td>17 643 (92.05)</td>
</tr>
<tr>
<td>SSI</td>
<td>129 (0.67)</td>
<td>413 (3.01)</td>
<td>407 (2.3)</td>
<td>318 (1.97)</td>
<td>1267 (7.95)</td>
</tr>
<tr>
<td>Total</td>
<td>6201 (32.35)</td>
<td>8090 (43.06)</td>
<td>3152 (16.62)</td>
<td>1467 (7.97)</td>
<td>18 910 (100)</td>
</tr>
<tr>
<td>Infection rate</td>
<td>2.1</td>
<td>5.1</td>
<td>12.9</td>
<td>21.7</td>
<td>6.7</td>
</tr>
</tbody>
</table>

SSI = surgical site infection.

* $\chi^2$: 80.112, $p < 0.001$.
† Unless indicated otherwise.

**Table 2. Rate of surgical site infection by patient ASA class**

<table>
<thead>
<tr>
<th>Variable</th>
<th>1 (no. %)†</th>
<th>2 (no. %)†</th>
<th>3 (no. %)†</th>
<th>4 (no. %)†</th>
<th>5 (no. %)†</th>
<th>Total (no. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No SSI</td>
<td>8061 (42.06)</td>
<td>3585 (18.7)</td>
<td>4158 (21.69)</td>
<td>1629 (8.5)</td>
<td>210 (1.1)</td>
<td>17 643 (92.05)</td>
</tr>
<tr>
<td>SSI</td>
<td>221 (1.67)</td>
<td>258 (1.66)</td>
<td>417 (2.55)</td>
<td>319 (1.77)</td>
<td>52 (0.3)</td>
<td>1267 (7.95)</td>
</tr>
<tr>
<td>Total</td>
<td>8282 (43.73)</td>
<td>3843 (20.36)</td>
<td>4575 (24.24)</td>
<td>1948 (10.27)</td>
<td>262 (1.4)</td>
<td>18 910 (100)</td>
</tr>
<tr>
<td>Infection rate, %</td>
<td>2.7</td>
<td>6.7</td>
<td>9.1</td>
<td>16.4</td>
<td>19.9</td>
<td></td>
</tr>
</tbody>
</table>

ASA = American Society of Anaesthesiologists; SSI = surgical site infection.

* $\chi^2$: 98.135, $p < 0.001$.
† Unless indicated otherwise.
Finally, we performed a multiple logistic regression (Table 4), from which we extracted the following information. Significant risk factors in superficial SSIs were environmental contamination by fungi (≥ 6 CFU, RR 6.2) and bacteria as well as surface contamination by both fungi and bacteria. Also important were humidity, differential pressure and temperature. The factors that were associated with the onset of deep and organ/space SSI were ASA class, patient-related factors (age, sex, nutrition), transfusion, type of intervention and days of preoperative stay. Some factors were common to both superficial and deep organ/space SSIs: antibiotic prophylaxis, shaving with electric razor, duration of the intervention and dirty intervention type.

**DISCUSSION**

The SSI rate in our study was rather high at 6.7%, but it should be noted that we included somewhat aggressive interventions in our analysis. Rates of SSI can vary significantly in the literature depending on several factors. There may be a combination of different interventions and surgical services with different SSI rates, or the study design might be retrospective or prospective. Above all, the rates oscillate depending on whether follow-up is carried out after patient discharge. For example, a study reported an SSI rate of 3.1%, but the study design was retrospective and did not include postdischarge follow-up. Another study reported a rate of just 1.0%, but it was carried out by analyzing administrative discharge registers and included only 7 surgical procedures. Another multicentre study, which reported a rate of 5.0%, was carried out over a period of just 1 month. Moreover, there can be variations in the definition of the term “surgical infection.” In broad strokes, reviews have reported SSI rates ranging from 1.5% to 20.0%. Therefore, in order to optimize the comparability of the results, it is necessary to define the parameters of SSI studies.

We found that older age and female sex were significant risk factors for deep organ/space SSIs, which is in line with the findings of previous studies on postcolorectal infections and cardiac surgery. The mean age of patients with SSIs in our study was 67.5 years, which is very close to the mean reported in other studies. However, the effect of the age variable is more nuanced; Mintjes-de Groot and colleagues found age to be a risk factor, and in our study, it approached the threshold for statistical significance. On the other hand, its effect may decrease when associated with more clear-cut factors, such as comorbidity and nutrition level.

With regards to the type of intervention, we observed a higher risk for SSI for operations classified as dirty. The results were statistically significant (OR 1.71, \( p = 0.032 \)) for superficial SSI and OR 5.16, \( p < 0.001 \) for deep organ/space SSI.

Correct antibiotic prophylaxis was one of the most important factors in avoiding SSI. We studied both the choice of the antibiotic and the time of administration, which have been shown to be relevant. Appropriate use of the antibiotic can be even more important in specific interventions, such as colorectal surgery; Hrivnak and colleagues go so far as to suggest local administration. Furthermore, antibiotics protect the patient even when — as is frequent — surgical gloves are torn during the procedure.

For many years, it has been known that the use of manual razors before surgery increases the incidence of wound infection compared with clipping, depilatory use, or no hair removal at all. In our study, the use of electric razors compared with manual razors was very important, resulting in an OR of 0.15.

Some studies have shown that preoperative hospital stay is associated with an increased risk of SSI, but this is masked because infections occurred in patients with greater severity or comorbidity. Our study shows that both length of preoperative stay and comorbidity increase the risk for SSI.

Despite the fact that in some randomized controlled trials, preoperative nutritional therapy did not reduce incisional and organ/space SSI risk, our results corroborated...
others showing that the hypoalbumin level of the patient was a significant factor.12,13,17

Environmental biosafety factors

When analyzing the environmental biosafety factors, it is worth remembering that many standards have been proposed to better control infections, but we could not identify any studies in the scientific literature anywhere in the world that contained an exhaustive recounting of all of the interrelated factors included in the present study.12,17 The scientific community generally accepts that laminar flow of ultraclean air and the use of HEPA filters over a relatively large area creates a field of air intended to isolate the surgical area and team and that these factors help prevent the development of SSIs.25,26 All of the interventions carried out in our study met these basic conditions to prevent SSIs. Some investigators, such as Brandt and colleagues,27 propose turbulent flow; however, their study was retrospective, based on routine surveillance data in 63 departments in Germany and limited in terms of the procedures included. It has been suggested that the measurement of air particle concentration could be used as an indicator of microbiological contamination,28 but studies by Friberg and colleagues29 and Landrin and colleagues30 could not find a statistical correlation, and they recommend continuing to measure the microbiological contamination. Recently other authors have carried out similar studies, concluding that further research is still necessary to identify substitutes for these procedures.31

Our study highlights the importance of contamination, mainly environmental, by fungi (≥ 6 CFU, OR 6.2). It also supports the statement that various measures for the control of the superficial SSI can be highly effective.12 Like other authors,13 we observed seasonal variations in the frequency of fungi, with lower levels in autumn and winter; however, the most common fungus in our study was Penicillium rather than the previously reported Aspergillus. With regard to the number of CFU found in our study, these were quite low compared with the levels published elsewhere14 in studies that observed the lowest levels of CFU in operating rooms with 12 ± 14 CFU/m³. Even so, the level of contamination was much lower than that observed outside. Moreover, some authors attest that the best way to measure the level of contamination in an operating room is through the use of a dusting cloth or DC pads, a simple flannel tampon (Ø 4.5 cm) prepared by covering a cotton disk that can be sewn to any type of surface and will detect more than twice the CFU as the standard Rodac contact.15

Although they are equipped with air conditioning systems that use HEPA filters, most of the operating rooms were found to contain airborne fungi, albeit at lower concentrations than those found in the other environments monitored.15 Furthermore, such contamination may be caused or exacerbated by a range of factors, such as non-compliance with procedural norms (e.g., the frequent opening of doors between the operating room and the outer environment) and inefficient operation or inadequate maintenance of the air conditioning system.11 Our study supports all efforts of recent technological advances in this field that aim to reduce environmental contamination.

Table 4. Logistic regression of surgical infections and environmental factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Superficial SSI</th>
<th>Deep organ/space SSI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)*</td>
<td>p value</td>
</tr>
<tr>
<td>ASA class*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.86 (1.01–3.42)</td>
<td>0.041</td>
</tr>
<tr>
<td>3</td>
<td>1.96 (1.15–3.34)</td>
<td>0.018</td>
</tr>
<tr>
<td>4</td>
<td>3.74 (1.45–9.62)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>5</td>
<td>5.83 (2.03–16.69)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Low albumin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC bacteria</td>
<td>1.75 (1.52–2.02)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>EC fungi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2–5</td>
<td>3.41 (1.02–11.39)</td>
<td>0.04</td>
</tr>
<tr>
<td>≥ 6</td>
<td>6.23 (2.02–19.13)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>SC bacteria</td>
<td>1.96 (1.49–2.16)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>SC fungi</td>
<td>1.61 (1.22–2.58)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Comorbidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.85 (1.48–2.31)</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.03 (1.01–1.05)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Preoperative stay</td>
<td>1.22 (1.01–1.49)</td>
<td>0.041</td>
</tr>
<tr>
<td>Humidity</td>
<td>1.35 (1.28–1.43)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Immunosuppression</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Differential air pressure</td>
<td>1.31 (1.22–1.42)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Prophylaxis†</td>
<td>0.29 (0.12–0.66)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Depletion‡</td>
<td>0.15 (0.06–0.36)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Air renewal rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex§</td>
<td>2.28 (1.19–4.36)</td>
<td>0.016</td>
</tr>
<tr>
<td>Nasogastric tube</td>
<td>1.12 (1.02–1.23)</td>
<td>0.027</td>
</tr>
<tr>
<td>Temperature</td>
<td>1.27 (1.09–1.47)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Duration of intervention</td>
<td>2.05 (1.64–2.57)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Intervention type¶</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clean–contaminated</td>
<td>3.22 (1.47–7.02)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Contaminated</td>
<td>3.87 (1.58–9.44)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Dirty</td>
<td>1.71 (1.03–2.83)</td>
<td>0.03</td>
</tr>
<tr>
<td>Transfusion</td>
<td>3.11 (1.4–6.91)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

ASA = American Society of Anesthesiologists; CI = confidence interval; EC = environmental contamination; OR = odds ratio; SC = surface contamination; SSI = surgical site infection.

*ASA class 1 is the reference group.
†Yes is the reference group.
‡Manual razor is the reference group.
§ Men are the reference group.
¶Clean is the reference group.

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such as using a high-intensity narrow-spectrum light environmental decontamination system (HIINS-light EDS)\textsuperscript{16} or ultraclean airflow mobile units.\textsuperscript{37}

Our study also shows that when contamination levels were virtually zero, almost no SSIs occurred for a total of 17 643 interventions, providing a large margin from which to safely draw our conclusions. The zero contamination level may be a reflection of many factors associated with the surgical activity and therefore can be considered a global or outcome index of many others (e.g., professional interest, patient preparation). Unlike the results found by other researchers, such as Humphreys,\textsuperscript{18} the results of our study did not show the air renewal rate to be a significant factor affecting SSIs. However, it should be kept in mind that the operating rooms were kept in adequate conditions practically at all times and that the ventilation system was on all day.\textsuperscript{19}

We found that there were different risk factors associated with each type of surgical infection. Superficial SSIs were associated with environmental factors, such as environmental contamination by fungi ($\geq 2$ or more CFU) and bacteria, surface contamination, humidity, differential pressure and temperature of the operating room. However, the factors that determined the deep organ/space SSIs were more often associated with patient characteristics (age, sex, transfusion, nasogastric feeding and nutrition), type of intervention and preoperative stay.

Other studies reported associations between SSIs and some of these factors, but they reported on SSIs in general rather than on superficial and deep organ/space SSIs separately.\textsuperscript{2} Another possible factor is the fact that the operative attire of the staff was limited to the operating room.

Regarding all of these aspects of environmental control, we, like other authors, consider that those elements denominated as factors of environmental biosafety should be comprehensively standardized and monitored, a process that is already beginning to take place for the factors associated with patient preparation.\textsuperscript{40} Considering the severity of the consequences, the establishment of international operating standards of reference for environmental biosafety is an urgent challenge.

Limitations

Important limitations of this study should be emphasized. First, because there are marked differences in surgeons’ tendencies to diagnose SSIs, we did not allow a surgeon’s diagnosis alone to identify SSI cases.\textsuperscript{41} We could not minimize interhospital variations, including observer differences, different patient groups and operating room discipline. We could have misclassified variables in this study, but this was probably nondifferential, so this misclassification likely weakened the association between SSI and different risk factors.

CONCLUSION

Our results suggest the importance of environmental and surface contamination control to prevent SSIs.

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Competing interests: None declared.

Contributors: J.L. Alfonso-Sanchez and J.M. Martín-Moreno designed the study, J.L. Alfonso-Sanchez, I.M. Martinez, R.S. González and F. Botía acquired the data, which all authors analyzed. J.L. Alfonso-Sanchez, I.M. Martinez, R.S. González and F. Botía wrote the article, which all authors reviewed and approved for publication.

References

Effects of electrospun scaffolds of di-O-butyrylchitin and poly-(ε-caprolactone) on wound healing

Background: We sought to determine the usefulness of electrospun dibutyrylchitin (DBC) or poly-(ε-caprolactone [PCL]), in wound treatment. We investigated the mechanisms of action of these polymers on wound healing.

Methods: We synthesized DBC, a newly identified ester derivative of chitin, using a patented method comprising the substitution of butyryl groups at positions C-3 and C-6 in chitin molecules. We confirmed the double substitution by the butyric groups using infrared spectrometry. The fibrous scaffolds were obtained using the electrospinning method. A polypropylene net was implanted subcutaneously in the rat and served as a wound model.

Results: Both DBC and PCL increased granulation tissue weight in the wound. In contrast to PCL, DBC did not abolish glycosaminoglycan changes in wounds. The tested samples did not impair total collagen synthesis or induce excessive fibrosis. In both PCL- and DBC-treated wounds, we observed a lower level of soluble collagen (compared with controls). The results show better hydration of the wounds in both the DBC and PCL groups. No induction of large edema formation by the tested materials was observed. These polymers induced almost identical macrophage-mediated reactions to foreign-body implantation. The implants increased the blood vessel number in a wound.

Conclusion: Both PCL and DBC could be used as scaffolds or dressings for wound treatment. The materials were safe and well tolerated by animals. As DBC did not disturb glycosaminoglycan accumulation in wounds and absorbed twice as much liquid as PCL, it can be considered superior.


Méthodes : Nous avons synthétisé le DBC, un dérivé ester récemment identifié de la chitine, à l’aide d’une méthode brevetée incluant la substitution des groupes butyryl aux positions C-3 et C-6 des molécules de chitine. Nous avons confirmé la substitution double par les groupes butyriques à l’aide de la spectrométrie infrarouge. Les échafaudages fibreux ont été obtenus grâce à la méthode de filage électrostatique. Un fil en polypropylène a été implanté par voie sous-cutanée dans le rat et a servi de modèle de plaie.

Résultats : Le DBC et le PCL ont tous deux augmenté le poids du tissu de granulation dans la plaie. Contrairement au PCL, le DBC n’a pas supprimé les changements des glycosaminoglycanes des plaies. Les échantillons examinés n’ont pas perturbé la synthèse totale de collagène ni entrainé une fibrose excessive. Nous avons observé un niveau inférieur de collagène soluble (par rapport aux témoins) tant dans les plaies traitées par PCL que par DBC. Les résultats montrent une amélioration de l’hydratation des plaies tant pour les groupes DBC que PCL. Les matériaux à l’étude n’induisaient pas d’œdème étendu. Ces polymères ont induit des réactions macrophagiques presque identiques à l’implantation d’un corps étranger. Les implants ont accru le nombre de vaisseaux sanguins de la plaie.

Conclusion : Tant le PCL que le DBC pourraient être utilisés comme échafaudages ou pansements pour le traitement des plaies. Les matériaux étaient sécuritaires et ont été bien tolérés par les animaux. Comme le DBC n’a pas perturbé l’accumulation des glycosaminoglycanes des plaies et a absorbé 2 fois plus de liquide que le PCL, il peut être considéré comme étant supérieur.
A material used for the scaffold should not only be a good medium for cell growth, but also should not disturb healing or induce excessive fibrosis. High porosity of scaffolds ensures good cell migration inside implants and a suitable environment for their proliferation.\textsuperscript{1,2} Di-\textit{O}-butyrylchitin (DBC) is an ester derivative of chitin. Synthesis of the polymer relies on the addition of butyric groups at positions C-3 and C-6 of chitin molecules. The method of DBC synthesis was described and patented.\textsuperscript{3,4} Moreover, the polymer features good biocompatibility and a lack of cytotoxicity.\textsuperscript{5–7} Experiments using implantation of a nonwoven mat made of DBC fibres into a wound model\textsuperscript{8} revealed that the polymer has a beneficial effect on the repair process. The greatest biological effects were observed using dibutyrylchitin, with a lower molecular mass of 123 600 g/mol,\textsuperscript{3,9} with an intrinsic viscosity in dimethylacetamide (DMAc) of 2.05 g/dL.

Poly-\textit{\varepsilon}-caprolactone (PCL) is applied as a drug delivery system for antibiotics or steroids.\textsuperscript{10,11} In addition, PCL is recommended for tissue engineering application as it exerts good compatibility with fibroblasts.\textsuperscript{11} The collagen-blended, porous nanofibrous membranes of PCL have been shown to be a good medium for the attachment and proliferation of fibroblasts, and could be applied as a scaffold for preparation of a skin substitute used to treat skin wounds.\textsuperscript{12–14}

Limited data exist regarding DBC biological effects. Previous papers have shown the beneficial effects of a nonwoven mat, made from classical DBC fibres, on wound healing.\textsuperscript{1,3,9} However, the influence of the thin fibrous structure of the material on wound repair has not yet been investigated. Therefore, the aim of the present study was to determine the influence of the electrospun thin DBC fibres on both the early and late stages of healing. In addition, we compared the results of the DBC experiments with the effects of PCL. We evaluated mechanisms of influence of the tested polymers on various phases of healing. Such a complex study addressing the physical and biological properties of PCL and DBC mats ensures better understanding of their influence on wound repair. Obtained findings are believed to define indications or contraindications of the material application in wound treatment.

**METHODS**

**Raw material**

We obtained DBC by the esterification of shrimp chitin (Lodz University of Technology). The effects of double substitution by the butyric groups were confirmed by infrared spectrometry (Fig. 1).

The molecular weight of the DBC was assessed using viscosimetry. Intrinsic viscosity was measured using a Ubelhode viscosimeter at 25°C with DMAc as the solvent (Sigma–Aldrich). We used DBC with an intrinsic viscosity of 1.93 g/dL in this study.

**Technology**

The electrospinning process was performed using a multinozzle laboratory stand designed and constructed at the Lodz University of Technology, Lodz, Poland.\textsuperscript{15} In this process, the polymer is delivered independently to each of the 32 spinning points of the spinning head of the stand. The spinning head is movable; the rate and the distance of movement are regulated. The electrostatic field is created by a high-voltage generator, and the applied voltage ranges from 0 kV to 50 kV. The distance between the nozzles and the collector was regulated across a range of 0.1–0.8 m. The electrospinning processes were optimized for both DBC and PCL.

**Measurements**

The thicknesses of the fibres and the web structure were analyzed using LUCIA G image analysis software (Laboratory Imaging). Porosity and pore size distribution were assessed using mercury porosimetry (AUTOPORE IV apparatus, Micromeritics) within a pressure range of 0.0036–412 MPa.\textsuperscript{16}

As the bioresorbability of a polymer is influenced by its crystallinity, we assessed the supramolecular structure. The degree of crystallinity was measured using X-ray diffractometry (Bruker). Changes in supramolecular structure were analyzed using WAXSFIT software (University of Bielsko-Biala). We used the method of Hindeleh and Johnson\textsuperscript{17} to analyze WAXS patterns using WAXSFIT.

![Infrared spectra of di-\textit{O}-butyrylchitin (grey line) and initial shrimp chitin (black line). The strong absorption visible on the spectra at 1738 cm\textsuperscript{-1} comes from the carboxyl group in an ester bond. The increased numbers of –CH\textsubscript{3} and –CH\textsubscript{2} groups are associated with greater absorption at 2950–2850 cm\textsuperscript{-1}. Double substitution by ester groups is also confirmed by excellent solubility of the polymer in ethyl alcohol and dimethyl sulfoxide.](image)
RECHERCHE

Measurement of wettability and wicking

We used a tensiometer Radian series 300 (Thermo Scientific) to measure contact angle and wicking. The contact angle was measured by immersing 25 mm samples. Depth of immersion was equal to 4 mm. We used both distilled water and cell culture medium (Gibco) to measure contact angle. Changes in the mass of the sample were noted. The contact angle was calculated on the basis of the following equation:

\[
\cos \theta = \frac{F \cdot g}{\gamma \cdot PR}
\]

where \( \cos \theta \) is the contact angle, \( F \) is the force of interactions between samples and liquid at the point of first contact (in milligrams), \( g \) is the gravitational force (in square centimetres per second), \( \gamma \) is the surface tension of liquid (in dyne per centimetre), and \( PR \) is the surface of the contact (in square centimetres). We measured wicking of 10/00A0 mm samples. The depth of immersion was equal to 4 mm, and the duration of immersion was 5 minutes.

Biochemical evaluation of wound and local reaction after implantation

Animals
Eighty-four male Wistar rats weighing 240 g ± 30 g were housed with free access to commercial food and ad libitum access to tap water. The study was approved by the local Commission of Ethics in Lodz, Poland.

Study design
The animals were divided into 3 groups of 28 rats each: group 1 (control group) comprised rats implanted with a polypropylene net, group 2 comprised rats implanted with a polypropylene net covered by DBC, and group 3 comprised rats implanted with a polypropylene net covered by PCL. Each group comprised 4 subgroups of 7 rats. The implant was removed from the rat of the relevant subgroup after the second, fourth, eighth or twenty-fourth week of healing, respectively.

Wound model
A polypropylene net (3 cm × 2 cm) covered with 2 pieces of testing materials (DBC or PCL) was implanted subcutaneously in the left lumbar region. A polypropylene mesh was used as a control. An incision was made in the middle of the polypropylene implant. The incision was limited on each side by a 3 mm intact part of the net. After implantation, the skin wounds were closed with 5 sutures.

To measure the weight of the dry mass of the granulation tissue, the weight of the implanted polypropylene net with the nonwoven material was subtracted from that of the entire implant mass (polypropylene net with dry granulation tissue). Water content in the tissue was calculated by subtracting the dry tissue weight from the wet tissue weight and was expressed as a percentage of wet tissue weight.

Evaluation of the tensile strength of granulation tissue of the wound

The margins (3 mm each) connecting the 2 parts of the implants were cut off, so the 2 parts of the implant were linked only by granulation tissue. The breaking strength of the tissue was measured using a Instron Model 1112 Tensile Tester Machine. The maximal load of the measuring head was equal to 2 kg. The distance between clamps was 1 cm, and the test velocity was equal to 100 mm/min. On the basis of stress curves obtained during the stretching of samples, we determined the maximal force at breakage.

Determination of collagen
To assess soluble collagen, the macerated tissue was suspended in 10 times its weight of 0.45 M of sodium chloride (NaCl) solution with penicillin (10 000 units/sample) and kept for 24 hours at 2°C. The mixture was evaporated to dryness.

After hydrolysis with 6 N of hydrogen chloride (HCl), all the samples were evaporated to dryness, and the precipitates were dissolved in distilled water and neutralized by 1 N of sodium hydroxide (NaOH). Hydroxyproline was oxidized to pyrrole by chloramine T in a citrate buffer. The perchloric acid was added to remove excess chloramine T. We then treated the samples with p-(dimethyl)aminobenzaldehyde and incubated them at 60°C for 20 minutes. The optical density was measured at 560 nm on a spectrophotometer.

Determination of glycosaminoglycans
Samples were homogenized and dried to a constant weight at 90°C. A 50 mg portion of the dried sample was added to a mixture composed of 0.75 M of NaOH and 50 mM of natrium borate. After incubation, the pH was neutralized with 6 M of HCl, and then trichloroacetic acid (TCA) was added to each sample to precipitate proteins. After centrifugation, we added 6 mL of 100% ethanol to the supernatant. For glycosaminoglycan (GAG) precipitation, the samples were kept at –20°C overnight and then centrifuged. The precipitate containing GAG was resolved in distilled water.

A 1.2 mL aliquot of dimethylmethylen blue (DMMB) reagent composed of 51 mM of 1,9-DMMB, 45 mM of glyoxal and 41 mM of NaCl adjusted to a pH of 3.0 with
1 M of HCl was added to 50 mL of the sample. The absorbance was measured at 525 nm on a spectrophotometer.\textsuperscript{19}

Alanine aminotransferase (ALT\textsuperscript{20}) and aspartate aminotransferase (AST\textsuperscript{21}) were assessed using kinetic methods. Jaffes’ method was applied for the evaluation of creatinine.\textsuperscript{22,23}

**Histological examination**

Samples were frozen without initial fixation at –24°C and then sliced on a cryotome and stained with hematoxylin and eosin. The samples were washed in 96% ethanol containing carboxylyene and xylene. The tissue was examined with a type 41 BX microscope (Olympus).

**Statistical analysis**

We used the Cochran Cox test for statistical analysis, and we considered results to be significant at $p < 0.05$. The null hypothesis was that differences between the average values of the determined variables of the studied samples and controls, as well as between samples, are statistically nonsignificant. The alternative hypothesis assumes that the differences between the studied samples and controls, as well as between samples, are statistically significant.

**RESULTS**

**Electrospinning of samples**

The DBC fibres were made from 6\% solution in ethyl alcohol (for a polymer with an intrinsic viscosity in DMAc of 1.93 g/dL). This solution was drawn into an electrostatic field formed by 28 kV, with the distance between the nozzles and the collector being 15 cm at an air temperature of 23°C and 78\% air humidity. Fibres with diameters of 2–10 mm (average 2.92 mm) were spun (Fig. 2).

The following optimal parameters for PCL fibre preparation were applied: polymer solution concentration 7.5wt\%, voltage 35 kV, distance between nozzles and collector 50 cm, temperature 13.6°C and air humidity 48\%. Two types of PCL fibres are shown on the micrograph displayed in Figure 3: very fine fibres with a diameter of 280 nm and thick ones with a diameter of 7.08 mm.

The DBC fibres were characterized by a 44\% degree of crystallinity, whereas the PCL fibres were found to have a 45\% degree of crystallinity (Table 1).

Most pores detected in samples had an average diameter of about 10 000 nm, although the DBC samples had smaller pores (200 nm in diameter), which gives an average value of pore diameter at the level of 2500 nm. The smallest pore diameter for nonwoven mats made from PCL was 1000 nm, but average pore diameter was at the level of 8000 nm (data not shown). Values of water advancing contact angle were lower for DBC than PCL, although both results suggest that the samples have hydrophobic characteristics. Contact angle values for cell culture medium for 2 samples were similar. We observed that DBC adsorbed twice as much liquid as PCL (Table 2).

The blood concentrations of creatinine, ALT and AST in rats treated with DBC or PCL were not significantly different from concentrations in controls (data not shown).

**Wound biochemistry**

We observed a gradual elevation of the dry tissue collected from the control wounds (Fig. 4). The weight of the granulation tissue in the twenty-fourth week in controls was significantly greater than the weight of the wounded tissue from the second week of experimentation in the same group. The weights of the dry tissue in wounds of the DBC group obtained in both the fourth and eighth weeks of healing were significantly higher than

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Fig. 2. Di-O-butyrylchitin (DBC) fibres formed from 6wt\% solution in ethyl alcohol. Technological parameters: voltage 28 kV, distance between nozzles and collector 15 cm, air temperature 23°C, humidity 78\%. Image A shows the web structure, and image B shows the fibre surface.
those obtained in the second week. Granulation tissue weight in the fourth and eighth weeks of DBC-treated rats was significantly higher than the corresponding control data. Although the weight of dry tissue in the DBC group was greater than in the PCL group during the eighth week of healing, it had decreased by the twenty-fourth week (Fig. 4). The weight of the granulation tissue of the PCL group reached a maximal level in the second week of healing and remained unchanged during all periods of observation. During the eighth week of healing, the weight of the tissue in the PCL-treated wounds was significantly higher than in controls.

We observed a progressive decrease in water content of the wounds in the controls and PCL-treated rats (Fig. 5). The lower water content in the wound was present in the fourth, eighth and twenty-fourth weeks in DBC-treated rats compared with the results obtained in the second week in the same group. The water content of the DBC group was higher than in controls and PCL-treated rats at both the eighth and twenty-fourth weeks after injury, indicating that DBC application to the wound prevented reduction in water content. In the PCL-treated group, lower water content was observed in the twenty-fourth week than in the second week. Moreover, in the eighth and twenty-fourth weeks of healing, significantly higher water content was found in PCL-treated rats than in the control group.

Glycosaminoglycan content in the granulation tissue of controls increased during repair, peaking from the fourth to the eighth week of the experiment and decreasing in the twenty-fourth week (Fig. 6). The GAG content of the wound was significantly higher in the fourth and eighth weeks than in the second week. This pattern of GAG changes was also observed in the DBC group and was abolished by PCL treatment. In the rats treated with DBC, GAG content in the wounds was higher in the fourth, eighth and twenty-fourth weeks than in the second week. The GAG content in the DBC-treated rats was markedly higher than in controls at the fourth and twenty-fourth weeks after implantation. In the

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![Fig. 3. Poly-($\varepsilon$-caprolactone [PCL]) fibres formed from 7.5wt% solution in ethyl alcohol. Technological parameters: voltage 35 kV, distance between nozzles and collector 50 cm, air temperature 13.6°C, humidity 48%. Image A shows the web structure, and image B shows the fibre surface.](image)

<table>
<thead>
<tr>
<th>Table 1. Structural characteristics of webs formed via electrospinning</th>
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<td>Treatment</td>
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<tr>
<td>DBC</td>
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<td>PCL, fine fibres</td>
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<td>PCL, thick fibres</td>
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DBC = di-O-butyrylchitin; PCL = poly-$\varepsilon$-caprolactone.

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<th>Table 2. Surface properties of webs formed via electrospinning</th>
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DBC = di-O-butyrylchitin; PCL = poly-$\varepsilon$-caprolactone.
PCL-treated rats, we observed a significantly higher level of GAG in both the second and twenty-fourth weeks of repair compared with controls.

Neither DBC nor PCL significantly influenced total collagen levels in the wounds (Fig. 7). In the control wounds, the soluble collagen content gradually decreased from the second week to the twenty-fourth week of healing. In both the DBC- and PCL-treated rats, the level of soluble collagen in the twenty-fourth week of healing was significantly lower than in the second week in either group. We found that DBC significantly decreased levels of soluble collagen from the second to the eighth week of wound healing compared with controls. Similarly, PCL reduced soluble collagen levels compared with controls from the second to the fourth week of wound healing.

In the control group, breaking strength gradually increased and peaked during the twenty-fourth week of wound healing (Fig. 9), and this effect was also observed in the DBC- and PCL-treated groups. However, during the fourth week of healing, the breaking strength of the wound was significantly lower in the DBC group than the control and PCL-treated groups.

Wound histology

The inflammatory reaction was similar between the experimental and control groups. The intensity of inflammation...
was low in all groups. Inflammatory infiltration consisted of the same profile of cells. Differences were present in the size and location of “foreign body–type” macrophages. They were smaller, more numerous and more closely localized to fibres in the both the DBC and PCL groups compared with controls (Table 3 and Figs. 10–12).

**DISCUSSION**

The parameters of the electrospinning process allow the formation of a fibrous web. (Table 1). The literature gives similar characteristics for PCL electrospun fibres. The DBC webs (Table 1) have a smaller pore diameter than PCL webs: pore diameters of approximately 200 nm were seen in DBC webs, whereas the lowest observed pore diameter for PCL webs was 1000 nm. In addition, the total pore area was higher for DBC material than PCL material (Table 1). The DBC fibres were also found to have a more uniform diameter than the PCL webs, whose fibres were of nonuniform thickness, with nonfibrous elements also visible (Fig. 3). The DBC fibres demonstrated an oblate shape in cross-section. These features of DBC material allow better arrangement of the fibres in a web and result in better compaction.

Water-advancing contact angles were lower for DBC than PCL, which suggests that DBC is less hydrophobic than PCL, although the results showed that the 2 samples had hydrophobic characteristics (Table 2). Differences between values of advancing and receiving contact angles suggest that PCL samples have better wettability (Table 2). The DBC samples adsorbed twice the volume of liquid as PCL webs (Table 2), which corresponded with the total pore area values for both PCL and DBC webs. Thus, the total pore area of a DBC sample is 3 times that of a PCL sample (Table 1).

The dry tissue content was much higher in both the fourth and eighth weeks of repair in the wounds treated with DBC than control wounds (Fig. 4). Previous reports revealed that the use of DBC doubled the cell number in culture and lowered the necrotic cell number. In addition, DBC has been hypothesized to increase cell viability. Therefore, the DBC-induced augmentation of the granulation tissue weight, which we also observed in the present study, could be explained by an increased fibroblast number in the granulation tissue of the wound. Chitin derivatives have also been reported to stimulate cell proliferation in vivo. The pattern of the granulation tissue reaction to PCL treatment was different than that observed in both control and DBC-treated wounds. Therefore, the maximal level of granulation tissue in the PCL group was reached in the second week of healing and remained unchanged throughout the observation period. Good cell growth and fibroblast proliferation has previously been observed in a PCL/gelatin nanofibre scaffold. The reaction of the tissue was different for both PCL and DBC, but neither polymer diminished granulation tissue production nor caused continuous excessive accumulation (Fig. 4).

Water content in the wound was decreased in the control group (Fig. 5). We observed a similar process in both DBC- and PCL-treated wounds. The results showed better hydration of the wounds in both the DBC and PCL groups than the control group. No induction of large edema formation by the tested materials was observed (Fig. 5). The hydration of DBC samples was twice that of PCL obtained in vitro; this contrasts with only slightly better liquid retention observed in DBC samples implanted subcutaneously (Fig. 5). This discrepancy is supposed to be dependent on cell migration into the implanted samples and accumulation of extracellular matrix. The cells and elements of the extracellular matrix may modify water homeostasis within the tested sample. The poorer hydration of PCL implants than DBC implants may be linked with the impaired GAG accumulation pattern observed in this polymer (Fig. 6).

![Fig. 9. Breaking strength of granulation tissue after 2, 4, 8 and 24 weeks of healing in controls and rats with dressings covered by di-O-butyrylchitin (DBC) or poly-ε-caprolactone (PCL). Each bar represents a mean ± standard deviation of 7 rats. *Significant (p < 0.05) differences between the tested group and controls.](image)

| Table 3. Histological examination results* |
|------------------|------------------|------------------|------------------|------------------|
| **Group**       | **Intensity of** | **Cellularity**  | **“Foreign body type”** | **Number of**   |
|                 | **inflammation** | **connective tissue** | **macrophages** | **blood vessels** |
| Control         | Low              | Low              | Low              | Low              |
| DBC             | Low              | Low              | Intermediate     | Intermediate     |
| PCL             | Low              | Low              | Intermediate     | Intermediate     |

*The histological features were classified as low, intermediate, or high.

DBC = di-O-butyrylchitin; PCL = poly-ε-caprolactone.
We observed a similar pattern of GAG level changes in the DBC and control groups. However, PCL implants altered the physiologic pattern of GAG changes in a wound (Fig. 6). Glycosaminoglycans are important regulators of the water–electrolyte balance in the tissue, modify growth factors and proteinase action, influence collagen fibre formation, and regulate gene expression.31

In the control group, the soluble collagen content decreased throughout the experiment (Fig. 8). The solubility of collagen in neutral salt solutions reflects its degree of maturation, cross-linking or catabolism.32 Collagen fibre maturation occurs when intermolecular covalent bond formation causes progressive loss of solubility of the molecule. In both the DBC and PCL groups, the soluble collagen level was lower in the second week of healing and persisted at the lower level for the duration of the experiment (Fig. 8). Thus, the 2 tested materials decreased the level of soluble collagen while the total collagen content remained unchanged (Fig. 7). This observation suggests that these polymers may increase the deposition of insoluble collagen in wounds treated with DBC or PCL.32,33

Histological studies show similar responses of the tissue to implantation of both PCL and DBC. The implantation of biomaterials (Fig. 10–12) triggers an inflammatory response, with fibrosis following. The nonstained fibres and macrophage-mediated foreign body response are visible in the tissue. PCL is hydrolytically degradable.34 The enzymatic degradability of DBC has been studied by Muzzarelli and colleagues,34 who noted that DBC was modestly degraded by lipases. Collagenase was able to adhere to fibres and to exert limited activity on them, but little hydrolytic activity was exerted by cellulase and pectinase. DBC treatment with lysozyme reduced the tensile strength of fibres and released oligomers.34–36 Wounds treated with either DBC or PCL showed increased vascularization compared with control wounds (Table 3). Enhanced angiogenesis and accelerated wound healing has also been observed after implantation of chitosan-hyaluronan membranes with adipose-derived stem cells to the wound in the rat.37

Fig. 10. Granulation tissue in controls at 24 weeks. Staining with hematoxylin and eosin. Magnification x200.

Fig. 11. Granulation tissue in the di-O-butyrylchitin (DBC) group at 24 weeks. Staining with hematoxylin and eosin. Magnification x200.

Fig. 12. Granulation tissue in the poly(ε-caprolactone [PCL]) group at 24 weeks. Staining with hematoxylin and eosin. Magnification x80.
of materials produced by classical methods from the same polymers. Tests of the surface properties of materials using water and cell culture medium indicate that interactions between tested materials and the media were significantly different. The higher values of wicking and the lower contact angle value suggest that the surface properties of the materials will not allow them to impede the passage of typical fluids existing in wounds. It should also be noted that better surface properties were observed for DBC samples.

The clinical effects of the polymers are dependent not only on the chemical composition, but also on the geometry and structure of the samples. The obtained pore sizes were sufficient for migration of the connective tissue cells, inflammatory cells and angiogenesis. The 2 scaffolds used induced adequate extracellular matrix synthesis in the wound. Thus, the DBC scaffold did not disturb the physiological course of repair of the wound and did not induce excessive fibrosis, edema or marked impairment of tensile strength. Ingrowth of the tissue into the sample after implantation modifies the hydrophilic properties of the polymers, but wounds treated with both PCL and DBC are significantly better hydrated. In both PCL and DBC samples, the process of degradation depends on the infiltration of macrophages. The resorption of the polymer is rather a long process that leaves degradation products that are neither nephrotoxic nor hepatotoxic.

CONCLUSION

The superiority of DBC was related to fact that, unlike PCL-treated wounds, it had not disturbed the pattern of GAG accumulation or had not reduced the weight of dry granulation tissue in the wound. Moreover, DBC webs absorbed twice as much liquid as PCL samples. Thus, dressings made of DBC could be recommended for the treatment of wounds with increased exudate. All other responses of the wounded tissue to DBC or PCL were similar, and both polymers could be used as scaffolds or dressings for wound treatment.

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Competing interests: None declared.

Contributors: J. Drobnik and I. Krucinska designed the study. J. Drobnik, A. Komisarczyk, S. Sporny and A. Szczepanowska acquired the data, which all authors analyzed. J. Drobnik, I. Krucinska, A. Komisarczyk and S. Sporny wrote the article, which all authors reviewed and approved for publication.

References


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Physician extenders on surgical services: a systematic review

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Background: With the introduction of resident duty hour restrictions and the resulting in-house trainee shortages, a long-term solution to ensure safe and efficient patient care is needed. One solution is the integration of nurse practitioners (NPs) and physician assistants (PAs) in a variety of health care settings. We sought to examine the use of NPs and PAs on surgical/trauma services and their effect on patient outcomes and resident workload.

Methods: We performed a systematic review of EMBASE, Medline, CINAHL, and the Cochrane Central Register of Controlled Trials. We included studies (all designs) examining the use of NPs and PAs on adult surgical and trauma services that reported the following outcomes: complications, length of stay, readmission rates, patient satisfaction and perceived quality of care, resident workload, resident work hours, resident sleep hours, resident satisfaction, resident perceived quality of care, other health care worker satisfaction and perceived quality of care, and economic impact assessments. We excluded studies assessing nonsurgical/trauma services or pediatrics and review articles.

Results: Twenty-nine articles met the inclusion criteria. With the addition of NPs and PAs, patient length of stay decreased, and morbidity and mortality were unchanged. In addition, resident workload decreased, sleep time increased, and operating time improved. Patient and health care worker satisfaction rates were high. Several studies reported cost savings after the addition of NPs/PAs.

Conclusion: The addition of NPs and PAs to surgical/trauma services appears to be a safe, cost-effective method to manage some of the challenges arising because of resident duty hour restrictions. More high-quality research is needed to confirm these findings and to further assess the economic impact of adding NPs and PAs to the surgical team.

Contexte : Compte tenu de la réduction du nombre d'heures de travail des médecins résidents et de la pénurie de stagiaires qui en a résulté, une solution à long terme s'impose pour assurer la sécurité et l'efficacité des soins aux patients. Une solution consiste à intégrer des infirmières praticiennes (IP) et des adjoints aux médecins (AM) dans divers contextes de soins de santé. Nous avons voulu examiner l'incidence du recours aux IP et aux AM dans des services de chirurgie et de traumatologie et son effet sur la santé des patients et sur la charge de travail des médecins résidents.

Méthodes : Nous avons procédé à une revue systématique des bases de données EMBASE, Medline, CINAHL et du Registre central Cochrane des essais contrôlés. Nous avons inclus les études (tous types de protocoles) ayant analysé le recours aux IP et aux AM dans des services de chirurgie et de traumatologie chez l’adulte ayant fait état des paramètres suivants : complications, durée des hospitalisations, taux de réadmission, satisfaction et perception quant à la qualité des soins chez les patients, charge de travail, heures de travail, heures de sommeil, satisfaction et perception quant à la qualité des soins chez les médecins résidents, satisfaction et perception quant à la qualité des soins chez les autres travailleurs de la santé et retombées économiques. Nous avons exclu les études qui évaluaient d’autres services que la chirurgie, la traumatologie ou la pédiatrie et les articles de synthèse.

Résultats : Vingt-neuf articles correspondaient aux critères d’inclusion. Avec l’intégration des IP et des AM, la durée des hospitalisations a diminué et la morbidité et la mortalité sont restées inchangées. En outre, la charge de travail des médecins résidents a diminué, leur temps de sommeil a augmenté et leur temps opératoire s’est amélioré. Les taux de satisfaction des patients et des travailleurs de la santé ont été élevés. Plusieurs études ont fait état d’économies après l’intégration des IP et des AM.

Conclusion : L’intégration des IP et des AM aux services de chirurgie et de traumatologie semble être une méthode sécuritaire et rentable pour gérer certains des défis qui découlent de la réduction des heures de travail des médecins résidents. Il faudra procéder à d’autres recherches de grande qualité pour confirmer ces observations et évaluer plus en profondeur les retombées économiques de l’intégration des IP et des AM aux équipes de chirurgie.
With the introduction of resident duty hour (RDH) restrictions and the resulting shortages of in-hospital trainee availability, a long-term solution to ensure safe and efficient patient care is needed. One of the most well-researched solutions is the integration of nurse practitioners (NPs) and physician assistants (PAs) in a variety of health care settings. These NPs and PAs, often called “midlevel practitioners,” “nonphysician providers,” or “physician extenders” (PEs), have been shown to be a safe and effective addition to health care teams. To avoid the negative connotation associated with the term “midlevel practitioners,” we prefer to use the term PEs to refer to NPs and PAs.

These practitioners differ in the training they have undertaken and in their background education. Nurse practitioners are registered nurses (RNs) who have met the requirements for working as bedside nurses and have then completed a graduate degree and training program. Physician assistants have an undergraduate education in a variety of disciplines, including life sciences and health care. They complete a PA training program and may or may not complete a graduate degree, depending on the requirements of their jurisdiction of practice. Both types of practitioners have the ability to prescribe, diagnose and perform medical procedures. The difference between the 2 types is that NPs can work autonomously and are registered under the College of Nurses of a specific jurisdiction, whereas PAs work under a physician or group of physicians and are registered under the respective College of Physicians. Both NPs and PAs have been shown to be valuable members of the health care team in a variety of settings.

With increasing physician workload and decreasing availability of in-house trainees, the use of NPs and PAs has become increasingly popular. Surgical services have been shown to value the importance of NPs and PAs, and evidence has shown the “value added” of having these practitioners on a surgical team in a variety of settings. These providers have been shown to improve access to care, decrease wait times, promote wellness and preventative care, provide continuity of care, foster interprofessional collaboration, improve follow-up, and decrease costs and readmission rates.

We performed a systematic review to examine the use of NPs and PAs on surgical/trauma services and their effect on patient outcomes and resident workload.

Methods

Following the PRISMA checklist (www.prisma-statement.org), we performed a systematic review of the literature on EMBASE, Medline, CINAHL, and the Cochrane Central Register of Controlled Trials in May 2015.

Inclusion criteria

- Randomized controlled trials (RCTs), cross-sectional studies, cohort studies, case series and surveys
- Studies examining the use of NPs and PAs on adult surgical and trauma services
- Studies reporting patient-related outcomes, including complications, length of stay (LOS), readmission rates, satisfaction and perceived quality of care
- Studies reporting resident-related outcomes, including workload, work hours, sleep hours, satisfaction and perceived quality of care.
- Studies reporting other health care worker–related outcomes, including satisfaction and perceived quality of care.
- Economic assessments of the use of NPs and PAs on adult surgical and trauma services

Exclusion criteria

- Studies evaluating NPs and PAs in nonsurgical or nontrauma services
- Studies pertaining to pediatric patient services
- Studies not examining the aforementioned outcomes
- Review articles
- Commentaries or letters to the editor

Search strategy

An example of the search strategy used when querying Medline can be seen in Figure 1. We queried each database and compiled the results, removing duplicates. Both of us then reviewed the titles independently, followed by abstract review. At both of these stages disagreement led to inclusion. Each of us then reviewed the full manuscripts of the selected abstracts, at which point consensus was necessary for inclusion. The reason for exclusion at the manuscript review stage is documented in Table 1.

One of us collected data relating to the specified outcome measures. Generic data, such as title, authors, study design, journal and year of publication, were recorded. Specific data relating to the outcomes described in the inclusion criteria were also recorded.

We assessed risk of bias of all included manuscripts (at the study level) using the Cochrane Collaboration’s assessment tool. Given the retrospective design of most of the included studies, a strong risk of bias exists. Most importantly, a strong risk of selective outcome reporting is present in all studies.

Heterogeneity and the qualitative nature of many of the outcomes precluded statistical analysis of the results.

Results

Included manuscripts

Twenty-nine articles from 29 different first authors met our inclusion criteria (Table 2 and Fig. 2). The most prevalent journal was the Journal of Trauma, having published
10 of the articles. Publication dates ranged from 1990 to 2014; however, 21 of the articles were published in the past 10 years. There were 15 case–control articles, 5 retrospective reviews, 8 surveys and only 1 RCT. Specialties included in the 29 articles were trauma service (11), cardiac/cardiothoracic/cardiovascular surgery (7), general surgery (4), orthopedic surgery (3), urology (1) and neurosurgery (1); 2 articles encompassed multiple surgical specialties. Most studies were case–control studies (15) or surveys (8). Overall the methodological quality and level of evidence of the included articles was low, with only 1 level-1 and 1 level-2 study included (Table 2). Notably, a risk of selective outcome reporting existed for all studies.

**Length of stay**

Of the 8 articles that examined patient LOS as an outcome, 7 (88%) found that LOS decreased after the addition of PEs to the service.7–14 One paper found the LOS unchanged. Six articles reported actual LOS improvements, which ranged from 0.25 to 2 days (Table 3). Three of the included papers also demonstrated a decrease in intensive care unit LOS.

**Morbidity and mortality**

None of the included studies demonstrated an increase in morbidity or mortality with the addition of PEs to the service in question. Two studies found that complication rates were decreased.12,15 One study found an increase in the rate of diagnosis of deep vein thrombosis after PEs became involved in patient care.11

**Procedures**

Two articles specifically reviewed procedures performed by PEs.16,17 Bevis and colleagues16 reviewed thoracostomy tube placement in trauma patients, comparing procedures performed by PEs to those performed by trauma surgeons. They found no difference in complication rates when PEs performed the procedure. Young and Bowling17 examined intracranial pressure monitor placement by PEs and found no significant difference in complication rates when compared with monitors placed by neurosurgeons. In addition, Sirleaf and colleagues18 found no difference in complication rates between procedures performed by residents or PEs, including arterial lines, central venous catheters, thoracostomy tubes, bronchoalveolar lavage, percutaneous endoscopic gastrostomy and tracheotomies.

**Effect on residents**

Nine papers examined the effect of PEs on surgical residents.7,9,19–25 The main effects documented included a decrease in overall resident work hours, increased operating room time, reduced number of pages, increased time for educational activities and increased sleep time. Victorino and Organ22 demonstrated decreased resident workload and stress levels and improved resident morale after the addition of PEs.

**Satisfaction**

Six studies found either improved or high patient satisfaction rates with the addition of PEs. None of the included articles demonstrated a decrease in patient satisfaction. Nine articles examined satisfaction rates of surgeons, residents and nursing staff and found overall high satisfaction rates.4,7,8,21,26–29 Improvements to patient care, continuity of care, communication with families, improved clinical documentation and reduced workload for other health care workers were all reported as reasons for the high satisfaction rates.

**Cost**

Five papers reported cost outcomes (Table 4).10,14,15,25,29 All 5 reported cost savings with the addition of PEs; however,
cost savings varied dramatically depending on the study. Decrease in the LOS of patients was responsible for significant cost savings in 2 articles. Bohm and colleagues demonstrated similar total costs with the addition of PEs; however, surgical volumes increased by 42%, and surgical wait times decreased after PEs were involved.

**DISCUSSION**

In surgical specialties, the volume of work can often exceed the capacity of the surgeons, trainees and nursing staff. This can lead to overworked and overwhelmed health care workers. With resident duty hours increasingly under the microscope of regulatory bodies, this problem has the potential to worsen dramatically. Patient safety and continuity of care continue to be highlighted as key issues in the discussion on work hour reform. These issues will persist at both teaching and nonteaching institutes until a sustainable model of care is developed.

Many hospitals have turned to NPs and PAs to help resolve the discrepancy between workload and already overworked employees. It is important that we critically examine the effect that these changes have on the hospital work environment, and most importantly on patient care, before advocating widespread adoption.

Our systematic review of the literature was undertaken to investigate the integration of PEs into surgical specialties and their effect on patients, surgical residents and other health care workers. Our results demonstrate overwhelmingly positive experiences among surgical services using PEs. Overall, patients and other health care workers report high satisfaction rates. Significant reductions in hospital and intensive care unit LOS have been reported after the addition of PEs to surgical or trauma services. Morbidity and mortality remain stable, and some studies have shown a reduction of in-hospital complication rates. An overall improvement in quality of care and continuity of care, as judged by health care workers, is a frequent theme in the studies we reviewed.

### Table 1. Excluded studies

<table>
<thead>
<tr>
<th>Reason for exclusion</th>
<th>No. of studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonsurgical/trauma services</td>
<td>20</td>
</tr>
<tr>
<td>Pediatric services</td>
<td>2</td>
</tr>
<tr>
<td>Selected outcomes not examined</td>
<td>15</td>
</tr>
<tr>
<td>Review article</td>
<td>5</td>
</tr>
<tr>
<td>Editorial</td>
<td>8</td>
</tr>
<tr>
<td>Meeting abstract</td>
<td>12</td>
</tr>
</tbody>
</table>
Table 3. Decrease in patient length of stay after the addition of PEs

<table>
<thead>
<tr>
<th>Year of publication</th>
<th>Study</th>
<th>Decrease in LOS, d</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>Spisso et al.</td>
<td>1.05</td>
<td>NR</td>
</tr>
<tr>
<td>1998</td>
<td>Miller et al.</td>
<td>0.70 (0.5 ICU)</td>
<td>NR</td>
</tr>
<tr>
<td>2005</td>
<td>Meyer and Miers</td>
<td>1.91</td>
<td>0.039</td>
</tr>
<tr>
<td>2006</td>
<td>Broers et al.</td>
<td>2.0</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>2011</td>
<td>Gillard et al.</td>
<td>0.25 (0.80 ICU)</td>
<td>0.092 (0.019 ICU)</td>
</tr>
<tr>
<td>2014</td>
<td>Collins et al.</td>
<td>0.55</td>
<td>0.024</td>
</tr>
</tbody>
</table>

ICU = intensive care unit; LOS = length of stay; NR = not reported; PE = physician extender.

Table 4. Manuscripts reporting cost savings

<table>
<thead>
<tr>
<th>Year of publication</th>
<th>Study</th>
<th>Reported cost savings</th>
<th>Rationale for cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>Meyer and Miers</td>
<td>$USD 5038.91/patient</td>
<td>Decreased LOS</td>
</tr>
<tr>
<td>2010</td>
<td>Bohm et al.</td>
<td>Same cost, with increased surgical volumes and decreased wait times</td>
<td>Eliminated need for fee-for-service surgical assist</td>
</tr>
<tr>
<td>2014</td>
<td>Collins et al.</td>
<td>$USD 9111.50/patient</td>
<td>Decreased LOS</td>
</tr>
<tr>
<td>2013</td>
<td>Althausen et al.</td>
<td>$USD 130/patient</td>
<td>Decreased patient time in ER, decreased OR setup time</td>
</tr>
<tr>
<td>2013</td>
<td>Skinner et al.</td>
<td>£ 168 653 (annual staff costs)</td>
<td>Annual staffing costs including locums</td>
</tr>
</tbody>
</table>

ER = emergency room; LOS = length of stay; OR = operating room.

Fig. 2. Study selection process. Central = Cochrance Central Register of Controlled Trials.
In addition, substantial cost savings were reported in several studies. Two groups reported savings of more than $5000 per patient.10,14 Bohm and colleagues29 reported increased surgical volumes and reduced wait list times without changes in expenditure. The studies reporting financial outcomes originated from 3 different health care systems (Canada, United States, United Kingdom), which decreases the generalizability of the results. None of the articles described in detail the funding sources for PEs. The study by Bohm and colleagues29 — the only Canadian study examining costs — reported that funding for the PEs came directly from the provincial health authority. Their cost savings came from eliminating the need for fee-for-service PAs, who are also paid directly by the health authority, in the operating room. This finding could potentially be generalizable to other Canadian health authorities. Given the complexity of hospital budgets, a funding model would likely have to come from the government level in most Canadian centres. Further detailed reports on cost-effectiveness and funding models are needed to help institutions advocate for and implement changes.

With resident duty hours being increasingly regulated, it would be prudent to maximize residents’ educational experiences while they are in hospital. For surgical residents, this means maximizing exposure to the operating room and clinics and minimizing administrative duties. Several studies have demonstrated that the addition of PEs to surgical services helps to accomplish those goals.7,19,21-25 Fewer pages and administrative duties have also been shown to increase resident sleep time and to reduce resident workload and stress levels, which may further maximize residents’ educational opportunities. Some institutions in Canada have increased the number of clinical fellows to address resident shortages. Some clinical fellows can fund their positions by billing as a surgical assistant, which eliminates the financial limitations for some institutions. This model runs the risk of degrading both resident and fellow learning experiences by overcrowding the operating room and clinic. We do not believe this is a stable, long-term solution to the problems at hand.

Any changes to current care models should take continuity of care into consideration. Any transition away from the reliance on residents and other trainees (at academic institutions) and 24-hour call shifts has the potential to increase the number of patient handovers between providers.32 Increased handovers may be a source of miscommunication or noncommunication of important patient issues.32,33 Appropriate, detailed handovers and the use of electronic charting/handovers may help minimize these issues.35 Handover of patients should be kept to a minimum; however, the current care models are becoming unsustainable. Our review demonstrates no difference in patient morbidity or mortality when PEs are included in the health care team, although the impact on handover processes have not been well described. Further reports detailing the ideal methods of integrating PEs (e.g., scheduling, handovers, provider roles) would be beneficial to institutions considering a transition to PEs.

Limitations

The main limitation of this review is the heterogeneity of the included studies, which makes the analysis of the results challenging. We attempted to present the important themes highlighted in the literature. In addition, the overall methodological quality of the included studies was low, which increases the risk of bias within the studies. We would advocate for further high-quality studies in this field to confirm the results of our review. As with any systematic review, important articles can be missed. By including a search of 4 major databases, we believe that risk was minimized.

CONCLUSION

The addition of NPs and PAs to surgical/trauma services appears to be a safe, cost-effective method to manage some of the challenges arising due to resident duty hour restrictions. Further high-quality research is needed to confirm these findings and to further assess the economic impact of adding NPs and PAs to the surgical team.

Affiliations: From the Department of Orthopedic Surgery, University of Calgary, Calgary, Alta.

Competing interests: None declared.

Contributors: A. Dodd designed the study. Both authors acquired and analyzed the data, wrote and reviewed the article and approved the final version for publication.

References

8. Miller W, Riehl E, Napier M, et al. Use of physician assistants as surgery/trauma house staff at an American College of Surgeons-
Comparing the tensile strength of square and reversing half-hitch alternating post knots

Background: Square knots are the gold standard in hand-tie wound closure, but are difficult to reproduce in deep cavities, inadvertently resulting in slipknots. The reversing half-hitch alternating post (RHAP) knot has been suggested as an alternative owing to its nonslip nature and reproducibility in limited spaces. We explored whether the RHAP knot is noninferior to the square knot by assessing tensile strength.

Methods: We conducted 10 trials for each baseline and knot configuration, using 3–0 silk and 3–0 polyglactin 910 sutures. We compared tensile strength between knot configurations at the point of knot failure between slippage and breakage.

Results: Maximal failure strength (mean ± SD) in square knots was reached with 4-throw in both silk (30 ± 1.5 N) and polyglactin 910 (39 ± 12 N). For RHAP knots, maximal failure strength was reached at 5-throw for both silk (31 ± 1.5 N) and polyglactin 910 (41 ± 13 N). In both sutures, there were no strength differences between 3-throw square and 4-throw RHAP, between 4-throw square and 5-throw RHAP, or between 5-throw square and 6-throw RHAP knots. Polyglactin 910 sutures, in all knot configurations, were more prone to slippage than silk sutures (p < 0.001).

Conclusion: The difference in mean tensile strength could be attributed to the proportion of knot slippage versus breakage, which is material-dependent. Future studies can re-evaluate findings in monofilament sutures and objectively assess the reproducibility of square and RHAP knots in deep cavities. Our results indicate that RHAP knots composed of 1 extra throw provide equivalent strength to square knots and may be an alternative when performing hand-ties in limited cavities with either silk or polyglactin 910 sutures.
Knot tying is a basic surgical technique that allows sutures and ligatures to resist physiologic wound expansion during the normal healing process. Failure of surgical knots can lead to complications postsurgery, especially for internal repairs within deep body cavities that cannot be readily visualized under direct observation.

The mechanism of knot failure is divided into slippage and breakage. When referring to the knot configurations, a throw denotes the weaving of the suture strands, with a knot consisting of 2 or more throws in succession. If an inadequate number of throws are used in the knot construction, the main mechanism of failure is by slippage or unravelling of the knot. The degree of slippage depends on a variety of factors, including knot type, suture material, suture gauge and moisture. With additional throws, increased friction is created between the suture materials, transitioning the mechanism of knot failure from slippage to breakage. The point where the suture breaks is most often at the knot, with the force required to break a knot lower than that of the untied suture material. Increasing the number of throws during knot construction increases knot strength, but only up to the point where the mechanism of failure transitions from slippage to breakage.

When all knots fail by breakage, additional throws will not provide increased tensile strength. The square knot is a type of reef knot with a single-looped overhand throw, followed by a reversed overhand throw laid flat on top. Its counterpart, the surgeon’s knot, is a double-looped first-throw variation. Both have been used for nearly a century in wound repair and closure. Today, the square knot is used as the gold standard for freehand knot tying in surgery, as it is the most secure especially when there is risk of tearing through delicate tissue. However, because of the flat nature of the square knot, it is difficult to reproduce during surgery, as tension must be applied equally to both ends of the strand perpendicular to the axis of the knot. This is especially the case when tying a square knot within the limited space of a deep body cavity, where throws inadvertently not laid parallel to one another, often owing to greater tension applied to one strand of the suture, can create a slipknot. This is also known as the nonalternating post knot, which is generally weaker and has a greater chance of failure, as it is more prone to slippage.

The reversing half-hitch alternating post (RHAP) knot is an alternative to the square knot that addresses the issue of slippage seen in nonalternating post knots. The RHAP knot alternates posts with each successive throw to prevent the knot from sliding off of a single standing suture strand. The RHAP knot is also postulated to be easier to tie than the square knot within a deep cavity. Although it has been suggested that square knots and RHAP knots with 1 extra throw have similar strengths and knot security, quantitative comparisons of the strength of the square knot versus the RHAP knot have yet to be established.

In the present study we sought to assess whether the RHAP knot with an additional throw could impart equivalent strength to the square knot by examining the tensile breaking strengths and mode of failures of each using an array of suture materials.

**METHODS**

**Materials**

Experiments were conducted in the Biomedical Laboratory at the Human Mobility Research Centre, Kingston General Hospital, Ontario, Canada. The ElectroForce 3500 Static Pull Machine (Bose Corporation) was used to measure the critical tensile breaking strength of each suture knot. We tested the RHAP and square knots with 3–0 gauged silk (PERMA-SILKO, Ethicon), polyglactin 910 (VICRYLÒ, Ethicon), polypropylene (PROLENEÒ, Ethicon) and polydioxanone (PDSÒ II, Ethicon) sutures. However, polypropylene and polydioxanone monofilament sutures underwent plastic deformation and irreversible stretching of the suture material and did not fail by breakage during baseline or knot configuration testing. Thus, we excluded monofilaments from the final data analysis.

**Experimental setup**

Adapted from the experimental setup used by Trimbos to construct knotted suture loops, we tied suture knots around 2 cylindrical rods attached on a board to ensure reproducibility of the length of each loop. The rods were removable and allowed the sutures to be transferred to the static pull machine for assessment of knot strength. Knot failure by slippage was defined as 3 mm of loop elongation, and this criterion has been widely used in the evaluation of various suture and knot combinations.

One of us (V.W.) tied all knots to ensure consistency, as this was a commonly accepted method for knot construction across the literature on knot biomechanics.
Surgical loops were attached to the device via 2 mounting arms, with the suture knot free-hanging. Once properly positioned, the surgical loop was pretensioned by allowing the lower mounting arm to extend by the force of gravity and by fixing the lower mounting arm to its hanging length (Fig. 1). We assessed tensile loading by configuring the static pull machine to separate the mounting arms at a constant rate of 1 mm/s up to the maximal displacement of 10 mm. Ten trials were conducted for each knot configuration in each suture material. This sample size was based on previous studies of suture knot breaking strength. Mahar and colleagues\textsuperscript{13} were able to demonstrate a significant difference in the breaking strength of 3 knot configurations within 2 suture materials.

**Baseline testing**

Initial baseline testing was used to assess the inherent tensile strength of each suture material. A single strand of unknotted, dry suture was mounted onto the experimental setup by placing the suture material around the upper mounting arm and then looping each free end of the strand 3 times around the lower mounting arm, securing the loose ends in place with stainless steel self-locking forceps, thereby creating an unknotted loop of suture. Tensile forces on the suture material were automatically recorded from the static pull machine in Newtons. We defined the baseline tensile strength for each suture as the maximum force where the suture material either failed or stretched beyond 10 mm. We conducted 10 trials for each suture material to establish the baseline tensile strength.

**Square knot testing**

Surgical loops of each suture material (silk and polyglactin 910) were constructed under dry conditions, with square knots composed of 3–5 throws using standard surgical knot tying techniques.\textsuperscript{6} Using the commonly accepted knot nomenclature by Loutzenheiser and colleagues,\textsuperscript{15} the configuration of a 4-throw square knot was \(1 = 1 = 1 = 1\) (Fig. 2). These suture loops were then mounted onto the static pull machine to examine the association between the number of square knot throws and knot strength. We defined knot strength as the maximum force exhibited onto the surgical loop before knot breakage or knot slippage (exceeding 3 mm). Force measurements were automatically recorded by the static pull machine in Newtons. We conducted 10 trials for each suture material and square knot.

**RHAP knot testing**

The name of the RHAP knot denotes its construction and consists of 2 components. First, half-hitch throws alternate between forehand and backhand variations.
Second, tension on the suture strands alternates between the left and right hand, producing alternating standing posts for each consecutive throw. Suture loops were constructed using the RHAP knot configuration composed of 4–6 throws. As it was difficult to repeatedly tie a nonslip knot with 3 throws in the RHAP configuration, the knot was modified to include an additional same-sided hitch throw as the second throw, with subsequent alternating half-hitches reversing each time. Using the knot nomenclature, the configuration of a 5-throw RHAP knot was $S = S\times S\times S\times xS$ (Fig. 3E). The step-by-step construction of the 5-throw RHAP knot is shown in Figure 3A–E. Similar to the square knot tests, we conducted 10 trials for each suture material and throw number to study RHAP knot strengths. To allow for direct comparison to square knots, RHAP surgical loop mounting and tensile force measurements were conducted identically to the conditions used in the square knot tests.

Statistical analysis

We performed all statistical analyses using SPSS software version 21 (IBM). We considered results to be significant at $p < 0.05$. Data were initially analyzed with simple descriptive statistics, including frequencies and percentages for categorical data and means and standard deviations for tensile strength. Tensile strength was also plotted to assess the underlying distribution. Within each knot type, we compared different numbers of throws within each type of material for tensile strength using 1-way analysis of variance (ANOVA) and Tukey post hoc tests adjusted for multiple comparisons. For both silk and polyglactin 910 sutures, we compared RHAP knots against square knots for tensile strength using 1-way ANOVA with Tukey post hoc testing to reveal between-group differences. Finally, we used Fisher exact tests to assess suture material and whether they were prone to slippage or breakage, and we used $t$ tests to compare the difference in tensile strength at the point of knot failure between slippage and breakage. Although the tensile strength was normally distributed overall, we used box plots to illustrate the tensile strength of the material/knot combinations, as this provides a better visualization of the data than simple histograms.

RESULTS

Baseline testing with silk (Fig. 4A) and polyglactin 910 sutures (Fig. 4B) revealed that the mean tensile breaking strengths of the suture material alone were $34 \pm 3.0$ N and $61 \pm 3.0$ N, respectively.

Square knot testing

The mean tensile strength of silk sutures for square knots in the 3-throw configuration ($24 \pm 3.2$ N) was significantly weaker than the 4-throw ($30 \pm 1.5$ N, $p < 0.001$) or 5-throw ($30 \pm 1.1$ N, $p < 0.001$) configurations. Interestingly, exceeding 4 throws did not increase the tensile

Fig. 3. Schematic for construction of reversing half-hitch alternating post (RHAP) knot, 5-throw configuration. The arrow depicts standing post. A) 1-throw, B) 2-throw same post, C) 3-throw alternating post, D) 4-throw alternating post, E) 5-throw alternating post.
strength of the silk square knot ($p > 0.99$). Similarly, the mean tensile strength of polyglactin 910 sutures for square knots in the 3-throw configuration ($29 \pm 8.5$ N) was significantly weaker than the 4-throw ($39 \pm 12$ N, $p = 0.048$) or 5-throw ($45 \pm 5.6$ N, $p = 0.001$) configurations. Again, with polyglactin 910 sutures, the 4-throw square knot configuration was statistically as strong as the 5-throw configuration ($p = 0.29$).

**RHAP knot testing**

Examination of RHAP knots in silk sutures revealed that the 4-throw configuration had a mean tensile failure strength of $23 \pm 3.4$ N, whereas 5- and 6-throw configurations both failed at a mean tensile strength of $31 \pm 1.5$ N and $31 \pm 1.2$ N, respectively. The 4-throw RHAP knot was significantly weaker than the 5-throw ($p < 0.001$) and the 6-throw ($p < 0.001$) configurations. Maximal tensile strength in silk sutures was reached with the 5-throw configuration; the 5-throw configuration did not differ significantly from the 6-throw configuration ($p > 0.99$). Similarly, with polyglactin 910 sutures, 4-throw knots failed at a mean tensile strength of $23 \pm 15$ N, which was significantly weaker than the tensions exhibited with 5-throw ($41 \pm 13$ N, $p = 0.013$) and 6-throw ($45 \pm 12$ N, $p = 0.002$) configurations. Knots in the RHAP configuration with polyglactin 910 sutures also reached maximal strength with the 5-throw configuration ($p = 0.72$).

**Square versus RHAP knots**

When examining the tensile strength of square versus RHAP knots using silk sutures (Fig. 4A), we found no significant difference in mean tensile strength between the 3-throw square and the 4-throw RHAP knot ($p = 0.64$), between the 4-throw square and 5-throw RHAP knot ($p = 0.93$), or between the 5-throw square and 6-throw RHAP knot ($p = 0.96$) configurations. These results were mirrored for polyglactin 910 sutures (Fig. 4B). A summary of the comparisons can be found in Table 1.

**Mechanism of failure**

Direct comparison of the suture material types demonstrated that polyglactin 910 knots, in both the square and

<table>
<thead>
<tr>
<th>Table 1. Mean breaking strength of various knot configurations in silk and polyglactin 910 sutures</th>
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<tbody>
<tr>
<td><strong>Square knot</strong></td>
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<tr>
<td><strong>Suture material</strong></td>
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<tr>
<td>Silk</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Polyglactin 910</td>
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*Tukey post hoc test.

* RHAP = reversing half-hitch alternating post knot; SD = standard deviation.
RHAP configurations, were more prone to failure by slippage than silk knots ($p < 0.001$). Failure by slippage was also achieved at a lower tension than failure by breakage for both silk ($p < 0.001$) and polyglactin 910 sutures ($p < 0.001$). However, knot slippage decreased as the number of throws per knot increased, independent of knot type. A detailed breakdown of mechanism of failure can be found in Table 2.

**Discussion**

Suture failure can negatively impact surgical outcomes, causing serious complications postoperatively. The present study reaffirmed the current literature that suture strength varies depending on the material.$^{16}$ Silk sutures were weaker than polyglactin 910 sutures at baseline and when comparing across the same knot configuration. Suture material also played a role in determining the mechanism of failure. We noted that polyglactin 910 was a stronger braided suture than silk; however, polyglactin 910 was more prone to slippage than silk within the same knot configuration. Even at the highest number of tested knot throws (5-throw square and 6-throw RHAP) slippage still occurred. This is an important takeaway from our study, as surgeons need to recognize that the inherent differences in suture material may contribute differently to the mechanism of knot failure. Additional throws may be required when using polyglactin 910 sutures to completely resist slippage.

In addition, we observed that all knotted sutures failed at the point of the knot, not elsewhere on the suture. In accordance with previous studies performed on knot mechanics, our study adds further evidence that the introduction of a knot can decrease the tensile strength of suture material.$^4$ Looking at the mechanism of failure, the difference in mean tensile breaking strength across the different knot configurations could be attributed to the proportion of knot slippage versus breakage. As noted in the results section, knots produced with fewer throws were more prone to slippage than breakage. The introduction of additional throws in a knot increases the contact surface area for the suture material, in turn increasing the amount of friction that the suture must overcome during motion. Knots with fewer throws would accordingly have less friction, allowing them to unravel at a submaximal tensile force. With subsequent throws, additional contact points are added to the knot, increasing the friction within the knot. We noted that at higher throws (4-throw square knot and 5-throw RHAP knot) the frictional force created by the additional throws exceeded the strength of the suture at the knot, thus transitioning the mechanism of failure from slippage to breakage. It is important to note that additional throws above this transition point did not yield any additional strength.

**Limitations**

Monofilament sutures (3–0 gauge prolene and PDS-II) were also tested in the present study. However, monofilaments were more prone to plastic deformation under loading by the static pull machine and subsequently did not experience knot failure by breakage or slippage. One of the limitations of the static pull machine was its 10 mm range of travel, which precluded the testing of prolene and PDS-II sutures. As such, these materials were not included in the final analysis.

Although our study was comprehensive for polyglactin 910 and silk sutures, future studies should assess RHAP and square knot performance in monofilament sutures to enhance the generalizability of the presented data. Moreover, future studies should explore the ease and reproducibility of RHAP versus square knots within deep body cavities. If such work can be completed, RHAP may be recommended as a suitable alternative to the square knot for free-hand knot tying within deep body cavities, thereby decreasing knot failure and its associated complications.

**Conclusion**

Our study highlighted that the RHAP knot, with 1 additional throw, was a noninferior alternative to the square knot with silk and polyglactin 910 sutures. Furthermore, our study reaffirmed that the mechanism of failure depends on suture material, that knot breakage occurred at the knot, and that knot slippage failed with less force than knot breakage.

**Affiliations:** From the School of Medicine, Faculty of Health Sciences, Queen’s University, Kingston, Ont. (Wu, Sykes); the Department of Surgery, Queen’s University, Kingston, Ont. (Mercer, Tang); the Clinical Research Centre, Kingston General Hospital, Kingston, Ont. (Hopman); and the Department of Public Health Sciences, Queen’s University, Kingston, Ont. (Hopman).

**Competing interests:** None declared.

**Contributors:** V. Wu, D. Mercer and E. Tang designed the study. V. Wu and E. Sykes acquired the data, which all authors analyzed. V. Wu, E. Sykes and E. Tang wrote the article, which all authors reviewed and approved for publication.

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**Table 2. Percentage of knot failure by slippage across all configurations and suture material**

<table>
<thead>
<tr>
<th>Knot configuration</th>
<th>Silk, % failure by slippage</th>
<th>Polyglactin 910, % failure by slippage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-throw</td>
<td>20</td>
<td>90</td>
</tr>
<tr>
<td>4-throw</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>5-throw</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>RHAP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-throw</td>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>5-throw</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>6-throw</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>47</td>
</tr>
</tbody>
</table>

RHAP = reversing half-hitch alternating post knot.
References

Factors affecting orthopedic residency selection: a cross-sectional survey

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Background: Annually, orthopedic residency programs rank and recruit the best possible candidates. Little evidence exists identifying factors that potential candidates use to select their career paths. Recent literature from nonsurgical programs suggests hospital, social and program-based factors influence program selection. We sought to determine what factors influence the choice of an orthopedic career and a candidate’s choice of orthopedic residency program.

Methods: We surveyed medical student applicants to orthopedic programs and current Canadian orthopedic surgery residents (postgraduate year [PGY] 1–5). The confidential online survey focused on 3 broad categories of program selection: educational, program cohesion and noneducation factors. Questions were graded on a Likert Scale and tallied for mean scores.

Results: In total, 139 residents from 11 of 17 Canadian orthopedic programs (49% response rate) and 23 medical student applicants (88% response rate) completed our survey. Orthopedic electives and mandatory rotations were reported by 71% of participants as somewhat or very important to their career choice. Collegiality among residents (4.70 ± 0.6), program being the “right fit” (4.65 ± 0.53) and current resident satisfaction with their chosen program (4.63 ± 0.66) were ranked with the highest mean scores on a 5-point Likert scale.

Conclusion: There are several modifiable factors that residency programs may use to attract applicants, including early availability of clerkship rotations and a strong mentorship environment emphasizing both resident–resident and resident–staff cohesion. Desirable residency programs should develop early access to surgical and operative skills. These must be balanced with a continued emphasis on top-level orthopedic training.

Contexte : Chaque année, les programmes de résidence en orthopédie évaluent et recrutent les meilleurs candidats possibles. On dispose de peu de renseignements au sujet des critères sur lesquels les candidats fondent leur choix de parcours professionnel. Selon la littérature récente issue de programmes non chirurgicaux, les critères de sélection des programmes ont à voir avec les hôpitaux, les programmes eux-mêmes et certains facteurs sociaux. Nous avons voulu savoir quels sont les facteurs qui influencent sur le choix d’une carrière en orthopédie et le choix d’un programme de résidence en orthopédie par les candidats.

Méthodes : Nous avons interrogé les étudiants en médecine candidats aux programmes d’orthopédie et les médecins résidents actuels en chirurgie orthopédique au Canada (année de résidence [R] de 1 à 5). Le questionnaire en ligne confidentiel portait sur 3 grandes catégories de critères de choix d’un programme : facteurs didactiques, facteurs liés à la cohésion des programmes et facteurs non didactiques. Les questions ont été classées sur une échelle de Likert et les scores moyens ont été estimés.

Résultats : En tout, 139 candidats et médecins résidents actuels de 11 programmes d’orthopédie sur 17 au Canada ont répondu au questionnaire (taux de réponse 49 %). Soixante et onze pour cent des participants ont qualifié les stages électifs et obligatoires en orthopédie de relativement ou très importants pour leur choix de carrière. La collégialité entre les médecins résidents (4,70 ± 0,6), l’adéquation des programmes (4,65 ± 0,53) et la satisfaction actuelle des médecins résidents à l’endroit du programme choisi (4,63 ± 0,66) ont obtenu les scores moyens les plus élevés sur l’échelle de Likert en 5 points.

Conclusion : Les programmes de résidence pourraient utiliser plusieurs facteurs modifiables pour attirer des candidats, y compris une offre de stage hâtive et un solide mentorat, mettant l’accent sur la cohésion résident–résident et résident–personnel. Les programmes de résidence attrayants devraient offrir un accès rapide aux compétences chirurgicales et opératoires. Et ces compétences devraient être en phase avec le maintien d’une formation orthopédique de haut niveau.
Annually, orthopedic residency programs rank and attempt to recruit the best possible candidates, which takes a substantial amount of time and effort. Several factors have been identified as relevant in helping residency programs evaluate and rank applicants.\(^1,2\) Applicants’ official transcripts, curriculum vitae, personal letters, references and performance at interviews are key components of the assessment process.\(^1,2,4,5\) Little evidence exists, however, identifying factors medical students and residents use to select their future career paths.\(^3\) Having a better understanding of these factors may help guide residency programs in attracting better candidates by emphasizing their strengths and potentially improving on areas of weakness.

A number of studies have evaluated orthopedic resident applicant selection.\(^3,5\) Recent literature has identified factors used by applicants in selecting emergency medicine residency programs.\(^6\) Factors influencing residency selection included program and staff reputation as well as hospital facilities provided by the institution. Other contributing factors included social and geographic influences. To our knowledge no study has looked specifically at factors that influence medical students and residents in choosing an orthopedic residency program. We feel that in addition to those items deemed important by emergency medicine applicants, orthopedic residency selection may involve items not considered by nonsurgical residency applicants, as surgical training has distinct challenges and requirements.

We surveyed medical student applicants and current Canadian residents from postgraduate year (PGY) 1–5. Survey contents assessed the qualities that make orthopedic residency programs desirable during the selection process and factors that residents find helpful in their current training programs.

The primary goal of our study was to establish the social, economic and program-specific characteristics that influence a candidate’s choice of orthopedic residency program. We evaluated similar factors previously identified for emergency medicine applicants.\(^3,6\) We hypothesized that the motivations influencing applicants in ranking an orthopedic residency program would differ from those reported for emergency medicine applicants. Additionally, our secondary goal was to determine if, retrospectively, the same selection factors were pertinent after applicants had matched and started working within an orthopedic residency program.

**Methods**

We designed an online questionnaire using SurveyMonkey addressing 5 broad categories: \(^1\) professional interests, attitudes and goals; \(^2\) training, certification and licensing; \(^3\) professional experience; \(^4\) well-being and leisure activities; \(^5\) and demographic information. Survey questions were derived from previous similar questionnaires in the literature.\(^5,6\) Along with 2 independent physicians, we reviewed the questionnaire for clarity and bias. Medical students and current orthopedic residents were surveyed using the questionnaire. Current residents were asked an additional question set focused on their experience in residency and whether their program met their educational and personal goals. Finally, we included a comments box to capture elements of the decision process that may not have been captured by the survey questions. The survey was electronically distributed to all 17 orthopedic residency programs in Canada. Participants were asked to complete the online questionnaire at their leisure. We also contacted the offices of each residency program director ahead of time to encourage enrolment and cooperation from residents. Medical students applying to the orthopedic program at our institution were recruited on a voluntary basis by supplying contact information during the application. A random prize draw incentive was offered to encourage voluntary participation.

We obtained informed consent electronically before the start of the online survey, and we obtained institutional review board ethics approval before initiation of the study.

**Participants**

Residents enrolled in a Canadian orthopedic surgery residency program and medical students applying to an orthopedic residency program were eligible to complete the questionnaire from January to June 2013. Residents from other nonsurgical and nonorthopedic programs and residents from foreign programs were not eligible to participate. The study’s primary outcomes were social, economic and program-specific characteristics affecting residency selection. Current program satisfaction was a secondary outcome.

**Statistical analysis**

A Likert scale was used to stratify responses from the questionnaire.\(^7\) We used descriptive statistical calculations to evaluate the data, establishing the mode measurements for each question and the distribution of responses. Likert scale responses were analyzed and mean scores were calculated for each factor by assigning numeric value to each response to obtain a rank for that factor (1 = not at all important or strongly disagree, 2 = not important or disagree, 3 = neutral or undecided, 4 = important or agree, 5 = very important or strongly agree). We calculated standard deviations for each mean score.

**Results**

Of a possible 284 respondents, 139 residents from 11 of the 17 residency programs completed the survey:
104 men (75%) and 35 women (25%) aged 25–34 years (49% response rate for orthopedic residents; Table 1). In addition, 23 of a possible 26 medical students interviewed at our institution participated in the survey (88% response rate). Resident respondents were distributed equally among the residency years (Table 2). Complete demographic data for study participants can be found in Table 1.

**Specialty selection**

A greater proportion of applicants decided to pursue a career in orthopedics during medical school (65%), whereas approximately one-third (35%) stated they wished to pursue orthopedics before medical school acceptance. If the decision to pursue orthopedics was made during medical school, the choice was primarily made during the third and fourth years (clerkship years, 71%). In total, 71% of students stated their mandatory orthopedic rotation was either somewhat or very important to their career choice. Interestingly, only 50% of medical school programs surveyed required a mandatory orthopedic rotation.

Mean scores evaluating relevant factors in selecting a career in orthopedics were ranked according to their importance (Table 2). Patient care aspects of orthopedics, including duration of surgery (exposure to the operating room as a trainee), patient population (diverse age and pathology on presentation), and type of work (surgical nature of the discipline) had the highest ranking (mean 4.6 ± 0.54). Considerations of lifestyle, work–life balance and job prestige were of moderate importance, with mean scores of 3.4 ± 1.09, 3.32 ± 1.14 and 3.23 ± 1.21, respectively. Research opportunities had the lowest mean score (2.69 ± 1.31), indicating a below-neutral importance for this factor.

**Residency program selection**

Residency program selection variables were divided into 3 categories: educational, program cohesion and non-educational factors. Our analysis of education mean scores demonstrated that sufficient patient exposure and variety, amount of early operative exposure and impression during elective time or summer research were the most important factors (4.50 ± 0.55, 4.49 ± 0.64 and 4.46 ± 0.88, respectively; Table 3). A competency-based program appeared to be of minimal importance for potential applicants, with a mean score of 2.43 ± 1.34.

Program cohesion variables, as measured by program collegiality, current resident satisfaction and program support for residents, are shown in Table 3. Resident–resident collegiality received the highest rank (mean 4.70 ± 0.60), followed closely by the program being the “right fit” and current resident satisfaction (mean 4.65 ± 0.53 and 4.63 ± 0.66, respectively). Prospective applicants reported resident–staff interactions to be a highly important selection variable (96%). All program cohesion variables obtained a mean score greater than 4.00, indicating that these factors were deemed important in residency program selection.

Program location and nearby recreational opportunities were felt to be the most relevant factors for extracurricular or noneducational factors, with mean scores of 4.26 ± 0.97 and 4.00 ± 1.05, respectively (Table 3).

A complete ranking of mean scores is presented in Table 4.

Overall, survey respondents felt the survey addressed the elements they considered important when selecting a residency program. In total, 64% of respondents felt the

### Table 1. Participant demographic characteristics (n = 139)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>35 (25.18)</td>
</tr>
<tr>
<td>Male</td>
<td>104 (74.82)</td>
</tr>
<tr>
<td><strong>Age, yr</strong></td>
<td></td>
</tr>
<tr>
<td>&lt; 18–24</td>
<td>5 (3.60)</td>
</tr>
<tr>
<td>25–34</td>
<td>117 (84.17)</td>
</tr>
<tr>
<td>35–44</td>
<td>13 (9.35)</td>
</tr>
<tr>
<td>≥ 45</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Not disclosed</td>
<td>4 (2.87)</td>
</tr>
<tr>
<td><strong>Relationship status</strong></td>
<td></td>
</tr>
<tr>
<td>Relationship, not married</td>
<td>50 (35.97)</td>
</tr>
<tr>
<td>Married</td>
<td>55 (39.57)</td>
</tr>
<tr>
<td>Divorced</td>
<td>2 (1.44)</td>
</tr>
<tr>
<td>Single</td>
<td>28 (20.14)</td>
</tr>
<tr>
<td>Not disclosed</td>
<td>4 (2.87)</td>
</tr>
<tr>
<td>Respondents with children</td>
<td>27 (19.42)</td>
</tr>
<tr>
<td><strong>Current level of training</strong></td>
<td></td>
</tr>
<tr>
<td>Medical student</td>
<td>23 (16.55)</td>
</tr>
<tr>
<td>Resident</td>
<td>116 (83.45)</td>
</tr>
<tr>
<td><strong>Postgraduate year</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>23 (19.83)</td>
</tr>
<tr>
<td>2</td>
<td>20 (17.24)</td>
</tr>
<tr>
<td>3</td>
<td>28 (24.14)</td>
</tr>
<tr>
<td>4</td>
<td>15 (12.90)</td>
</tr>
<tr>
<td>5</td>
<td>19 (16.38)</td>
</tr>
<tr>
<td>Not disclosed</td>
<td>11 (9.48)</td>
</tr>
</tbody>
</table>

### Table 2. Mean survey scores of factors relevant to selecting a career in orthopedics

<table>
<thead>
<tr>
<th>Factors</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient care</td>
<td>4.60 ± 0.54</td>
</tr>
<tr>
<td>Future income</td>
<td>3.75 ± 1.03</td>
</tr>
<tr>
<td>Work-life balance</td>
<td>3.40 ± 1.09</td>
</tr>
<tr>
<td>Lifestyle</td>
<td>3.32 ± 1.14</td>
</tr>
<tr>
<td>Job prestige</td>
<td>3.23 ± 1.21</td>
</tr>
<tr>
<td>Opportunities for research</td>
<td>2.69 ± 1.31</td>
</tr>
</tbody>
</table>

SD = standard deviation.
survey represented selection criteria very well or extremely well, whereas 30% felt the study analyzed these elements moderately well.

**DISCUSSION**

Our study’s aim was to develop an understanding of the social, economic and program-specific characteristics that help shape a candidate’s choice of orthopedic program selection. Our primary goal was to identify factors that attract applicants to their program of choice. Our results show that educational opportunities and program cohesion were most important; program elements such as institution and faculty reputation, early operative exposure and educational variety were of paramount importance (87%, 81%, 88% and 96% of respondents, respectively). Program cohesion, as measured by program collegiality and current resident satisfaction, was also important. Interestingly, 96% of applicants reported resident–staff interactions to be a highly important selection variable. In addition, 95% of applicants rated a feeling that the program was the “right fit” for them as important in their eventual program choice, followed closely by current resident satisfaction. The most important factor in program selection overall based on mean scores was collegiality among residents.

Cohesion variables all obtained a mean score of greater than 4.00, indicating that these variables were deemed relevant to program selection. No other category of program selection factors demonstrated this trend, suggesting the importance of program collegiality and support in residency program selection.

Noneducational aspects of a residency program received lower overall mean scores, suggesting they may play a less important role in the selection process. Only program location had a substantial number of respondents

### Table 3. Mean educational, noneducational and program cohesion survey scores

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Noneducational components</strong></td>
<td></td>
</tr>
<tr>
<td>Location of the program</td>
<td>4.26 ± 0.97</td>
</tr>
<tr>
<td>Recreational opportunities in the area</td>
<td>4.00 ± 1.05</td>
</tr>
<tr>
<td>Size of the community</td>
<td>3.92 ± 1.10</td>
</tr>
<tr>
<td>Influence on spouse/partner</td>
<td>3.66 ± 1.56</td>
</tr>
<tr>
<td>Ties to the community</td>
<td>3.39 ± 1.42</td>
</tr>
<tr>
<td>Call frequency</td>
<td>2.79 ± 1.27</td>
</tr>
<tr>
<td>Cost of living in the area</td>
<td>2.71 ± 1.28</td>
</tr>
<tr>
<td>Access to postcall days</td>
<td>2.59 ± 1.40</td>
</tr>
<tr>
<td>Resident salary</td>
<td>2.45 ± 1.17</td>
</tr>
<tr>
<td>Supplemental income opportunities</td>
<td>1.91 ± 1.04</td>
</tr>
<tr>
<td><strong>Educational components</strong></td>
<td></td>
</tr>
<tr>
<td>Sufficient patient exposure/variety</td>
<td>4.50 ± 0.55</td>
</tr>
<tr>
<td>Amount of early operative exposure</td>
<td>4.49 ± 0.64</td>
</tr>
<tr>
<td>Impression during elective time or summer research</td>
<td>4.46 ± 0.88</td>
</tr>
<tr>
<td>Level of responsibility</td>
<td>4.39 ± 0.54</td>
</tr>
<tr>
<td>Reputaiton of the institution</td>
<td>4.21 ± 0.89</td>
</tr>
<tr>
<td>Amount of didactic teaching</td>
<td>4.14 ± 0.78</td>
</tr>
<tr>
<td>Faculty supervision</td>
<td>4.14 ± 0.73</td>
</tr>
<tr>
<td>Reputaiton of the staff</td>
<td>4.13 ± 0.82</td>
</tr>
<tr>
<td>Impression at the interview</td>
<td>4.03 ± 0.95</td>
</tr>
<tr>
<td>Recommendation of the institution by staff</td>
<td>4.01 ± 0.87</td>
</tr>
<tr>
<td>Hospital facilities</td>
<td>3.99 ± 0.72</td>
</tr>
<tr>
<td>Recruitment by colleagues/residents/staff</td>
<td>3.91 ± 1.05</td>
</tr>
<tr>
<td>Research opportunities and facilities</td>
<td>3.33 ± 1.26</td>
</tr>
<tr>
<td>Competency-based programs</td>
<td>2.43 ± 1.34</td>
</tr>
<tr>
<td><strong>Program cohesion components</strong></td>
<td></td>
</tr>
<tr>
<td>Resident–resident collegiality</td>
<td>4.70 ± 0.60</td>
</tr>
<tr>
<td>Program was “the right fit”</td>
<td>4.65 ± 0.53</td>
</tr>
<tr>
<td>Current resident satisfaction with their program</td>
<td>4.63 ± 0.66</td>
</tr>
<tr>
<td>Resident staff interaction</td>
<td>4.46 ± 0.67</td>
</tr>
<tr>
<td>Program support for resident</td>
<td>4.34 ± 0.67</td>
</tr>
</tbody>
</table>

SD = standard deviation.

### Table 4. Rank of mean scores for factors influencing selection of a training program

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resident–resident collegiality</td>
<td>4.70 ± 0.60</td>
</tr>
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<td>4.65 ± 0.53</td>
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<td>4.63 ± 0.66</td>
</tr>
<tr>
<td>Resident staff interaction</td>
<td>4.46 ± 0.67</td>
</tr>
<tr>
<td>Program support for resident</td>
<td>4.34 ± 0.67</td>
</tr>
<tr>
<td>Location of the program</td>
<td>4.26 ± 0.97</td>
</tr>
<tr>
<td>Reputation of the institution</td>
<td>4.21 ± 0.89</td>
</tr>
<tr>
<td>Recreational opportunities in the area</td>
<td>4.00 ± 1.05</td>
</tr>
<tr>
<td>Hospital facilities</td>
<td>3.99 ± 0.72</td>
</tr>
<tr>
<td>Recruitment by colleagues/residents/staff</td>
<td>3.91 ± 1.05</td>
</tr>
<tr>
<td>Influence on spouse/significant other</td>
<td>3.66 ± 1.56</td>
</tr>
<tr>
<td>Ties to the community</td>
<td>3.39 ± 1.42</td>
</tr>
<tr>
<td>Research opportunities and facilities</td>
<td>3.33 ± 1.26</td>
</tr>
<tr>
<td>Proximity to current/previous medical school</td>
<td>2.98 ± 1.60</td>
</tr>
<tr>
<td>Call frequency</td>
<td>2.79 ± 1.27</td>
</tr>
<tr>
<td>Cost of living in the area</td>
<td>2.71 ± 1.28</td>
</tr>
<tr>
<td>Access to postcall days</td>
<td>2.59 ± 1.40</td>
</tr>
<tr>
<td>Weather</td>
<td>2.57 ± 1.26</td>
</tr>
<tr>
<td>Professional sports in the area</td>
<td>2.48 ± 1.26</td>
</tr>
<tr>
<td>Resident salary</td>
<td>2.45 ± 1.17</td>
</tr>
<tr>
<td>Competency-based program</td>
<td>2.43 ± 1.34</td>
</tr>
<tr>
<td>Supplemental income opportunities</td>
<td>1.91 ± 1.04</td>
</tr>
</tbody>
</table>

SD = standard deviation.
factors-strelzow.indd   190

ferences in the training atmosphere of high-demand, subtle distinctions may be associated with specific differences were of paramount importance to emergency medicine applicants. Although these criteria were important to orthopedic program applicants, they did not achieve the same mean scores as program cohesion variables. Secondly, important selection criteria for both emergency medicine and orthopedic applicants were personal factors and program location/recreational opportunities. These subtle distinctions may be associated with specific differences in the training atmosphere of high-demand, mentorship-based educational programs like orthopedic surgery, where program cohesion has a stronger influence on the trainee.

**Limitations**

To our knowledge, this study is the first of its kind to review factors guiding selection of an orthopedic residency program. There are a number of limitations to our study. First, its quantitative nature limits in-depth analysis of a complex decision-making process. Second, the response rate of 49% appeared to be low; however, this rate is quite respectable for an unsolicited survey. Third, the mix of medical student applicants and orthopedic residents from various years of training may have diluted the selection variables, and it is possible that our study did not accurately capture all the elements affecting orthopedic program selection. In addition, the inclusion of only medical students applying to our institution’s orthopedic training program inherently introduces selection bias owing to their underlying impetus and motivation to apply to our specific program; however, we could not control for this selection bias with the present study design. The low mean scores reported for the importance of research opportunities and competency-based programming on career choice may reflect our applicant pool or the preconceptions regarding our specific program. This selection bias may limit the widespread applicability of our results. Nonetheless, based on available Canadian Resident Matching Service data, approximately 25% of the overall medical student orthopedic applicant pool in 2013 was included in our study. The recruitment of additional medical students applying to all programs across the country would help reduce potential selection bias. Finally, the possibility of recall bias may have played a role in our results. Survey and questionnaire methodology requires residents to recall the factors that affected their selection of a program, but these factors may have undergone substantial change during the course of training. To control for this potential recall bias, multiple questionnaires over numerous years would be required to study its effect.

**Conclusion**

We feel this study identifies modifiable factors that orthopedic programs can use to enhance educational satisfaction for candidates. In an effort to optimize trainee and applicant satisfaction with an orthopedic training program, the development of a curriculum that includes team-building events, formalized mentorship programs between residents in different years and staff, and the incorporation of early and safe operative exposure or technique laboratories may help.

We hope to have raised awareness and interest in this topic with the goal of encouraging future research. Awareness of selection factors may help programs and departments develop or highlight these elements to future applicants. We believe that similar factors are likely of importance to all surgical residency applicants beyond orthopedics.

**Affiliations:** From the Department of Orthopaedics, University of British Columbia, Vancouver, BC.

**Competing interests:** None declared.
Contributors: All authors designed the study. J. Strelzow and R. Petretta acquired the data, which J. Strelzow analyzed. J. Strelzow and R. Petretta wrote the article, which all authors reviewed and approved for publication.

References


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A population-based study of outcomes in patients with gastrointestinal neuroendocrine tumours

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Background: Neuroendocrine tumours (NETs) are heterogeneous, with varying presentations and treatment options. To our knowledge, there are no randomized and few long-term studies of patient outcomes. The role of surgical and medical therapy for local, regional and metastatic disease continues to be evaluated in the literature.

Methods: We conducted a population-based search of the provincial cancer registry to identify patients with gastrointestinal NETs from the stomach, small intestine, colon and rectum diagnosed between 1990 and 2005 and assessed their outcomes.

Results: We examined clinicopathological information on the outcomes of 530 patients with gastrointestinal NETs. The overall incidence of NETs increased from 11 per million to 19 per million during the study period. Advancing stage and patient age were associated with poor overall or disease-specific outcomes. Surgery, both curative and palliative, was associated with decreased risk of overall (hazard ratio [HR] 0.5, \( p < 0.001 \)) and disease-specific (HR 0.5, \( p < 0.001 \)) death. The biggest benefit was observed in patients with distant disease, in whom 3-year disease-specific survival for R0 resections was nearly double that for patients with macroscopic residual disease (92% vs. 48%, \( p = 0.009 \)). Older age was associated with poor 5-year overall and disease-specific survival (\( p < 0.001 \)).

Conclusion: There has been a significant increase in incidence of gastrointestinal NETs, and advancing patient age, but not sex, is linked to poor outcomes in terms of overall and disease-specific survival. Surgery, both curative and palliative, was associated with decreased risk of overall and disease-specific death. Compared with patients with residual macroscopic disease, patients with distant disease were nearly twice as likely to survive 5 years if they had R0 resections. The use of radioisotope therapy and long-acting octreotide therapy was also associated with improved outcomes overall.

Contexte : Les tumeurs neuroendocrines (TNE) sont hétérogènes, et les tableaux et options thérapeutiques sont variables. À notre connaissance, il n’existe pas d’études randomisées et il y a peu d’études à long terme sur les résultats chez les patients. Le rôle du traitement chirurgical et médicamenteux de la maladie locale, régionale et métastatique continue d’être évalué dans la littérature.


Résultats : Nous avons examiné les données clinico-pathologiques des résultats enregistrés chez 530 patients atteints de TNE gastro-intestinales. L’incidence globale des TNE a augmenté de 11 par million à 19 par million pendant la période de l’étude. Le stade de la maladie et l’âge avancés ont été associés à des résultats globaux ou spécifiques à la maladie moins favorables. La chirurgie, curative et palliative, a été associée à un risque moindre de décès global (risque relatif [RR] 0.5, \( p < 0.001 \)) et spécifique à la maladie (RR 0.5, \( p < 0.001 \)). L’avantage le plus marqué a été observé chez les patients présentant une maladie distale, chez qui la survie à 5 ans spécifique à la maladie pour les résections R0 était près de 2 fois celle des patients présentant une maladie macroscopique résiduelle (92 % c. 48 %, \( p = 0.009 \)). L’âge avancé a été associé à une survie à 5 ans globale et spécifique à la maladie défavorable (\( p < 0.001 \)).

Conclusion : L’incidence des TNE gastro-intestinales a significativement augmenté, et l’âge avancé des patients, mais non le sexe, est lié à des résultats défavorables aux plans de la survie globale et spécifique à la maladie. La chirurgie, curative et palliative, a été associée à un risque moindre de décès global et spécifique à la maladie. Comparativement à des patients ayant une maladie macroscopique résiduelle, ceux qui avaient une maladie distale étaient près de 2 fois plus susceptibles de survivre 5 ans s’ils avaient des...
Neuroendocrine tumours (NETs), known historically as carcinoid tumours, were first described by Lubarsch in 1888. These tumours are distributed throughout the body but are mainly found within the gastrointestinal (GI) tract.\textsuperscript{1,2} Much of what is known about the incidence, distribution and outcomes of carcinoid or GI NETs has been derived from large population-based studies.\textsuperscript{3,4} One of the largest and most recent population-based studies of GI tumours was completed in the United States using the Surveillance, Epidemiology, and End Results (SEER) database, which documented a nearly 5-fold increase from 1979 to 2004 in the incidence of GI NETs.\textsuperscript{5} These data have been mirrored in a recent Canadian study.\textsuperscript{6} However, patient outcomes in large database studies are difficult to compare given the lack of uniform descriptions of staging as well as varying treatment paradigms for this disease. The general trends indicate that more than 75\% of patients survive 5 years and that the probability of survival is well reflected in stage classification of local, regional and distant disease.\textsuperscript{1,3,5,8-11}

We undertook a study of the incidence, presentation, stage, anatomic distribution and survival characteristics of GI NET tumours in a Canadian population served by 2 academic centres with a common cancer registry. We endeavoured to show that the incidence of these tumours has changed over time and to understand how patient outcomes vary with disease presentation and different treatment modalities.

\section*{Methods}
Alberta is the fourth most populous province in Canada, with a population of 3.8 million people. Between Jan. 1, 1990, and Dec. 31, 2005, all cases of gastric, small intestine, colonic and rectal NETs diagnosed in the province of Alberta were recorded in the Alberta Cancer Registry, as mandated by the Alberta Health Act. By probing this provincial registry, trained coders were able to identify all NETs diagnosed during the study period. Cases were excluded if the primary tumour location was not in the GI tract or if the pathology report was not consistent with a NET. Demographic characteristics extracted for each patient included age, sex and year of diagnosis. We extracted tumour-specific data, including clinical presentation, anatomic site of the tumour, stage at diagnosis (local, regional or metastatic) and evidence of carcinoid syndrome at diagnosis. The diagnosis of carcinoid syndrome was based on evidence of flushing, severe diarrhea, wheezing or cardiac symptoms consistent with elevated systemic 5-hydroxyindoleacetic acid (5-HIAA) or chromogranin A. We cross-referenced the registry data to 2 separate hospital data sets to confirm the completeness of the registry data. We were also able to obtain medical records from the Netcare electronic health repository or the Medical Records Department of the Cross Cancer Institute to validate the registry records. We assessed and validated the quality of the administrative data using the techniques outlined by Hinds and colleagues.\textsuperscript{12} In the present study we used the SEER staging system to compare outcomes. Stage of disease at presentation was defined as localized disease if there was no evidence of nodal involvement or distant metastatic disease, regional if there was evidence of nodal involvement, or metastatic. Anatomic location data were grouped as follows: stomach, small bowel, appendix, colon, rectum and other. We recorded whether the patient had surgery for either the primary tumour site or metastatic disease. The Alberta Cancer Board Research Ethics Board approved our study protocol.

\section*{Statistical analysis}
We calculated the annual incidence of new cases using the number of new cases diagnosed each year and the total population of the province for the corresponding year. Descriptive statistics were obtained for the study variables. We report means and standard deviations for the continuous variables and frequencies and proportions for categorical variables. For the purpose of analysis comparing survival data across different anatomic sites, we used the primary tumour site within small bowel as the reference group. We used Kaplan–Meier estimates and the respective 95\% confidence intervals (CIs) for median overall survival (OS) and disease-specific survival (DSS). We used log rank tests to compare the 2 survival curves, and we calculated age-adjusted 5-year OS and DSS rates for each stage, anatomic location and geographic location. To determine the predictors of OS and DSS, we used the Cox proportional hazard model. The final multivariate model was chosen with all the significant variables. All statistical analyses were conducted using SAS Software (SAS Institute Inc.), and we considered results to be significant at $p<0.05$.

\section*{Results}
A total of 530 cases of gastrointestinal NETs met our eligibility criteria. The overall incidence of NETs increased from 11 to 19 per million over the study period. The sex distribution did not vary significantly as a function of year in our study. Outcomes analyses historically used different staging criteria derived from different sources, including the American Joint Committee on Cancer (AJCC), European Neuroendocrine Tumor Society (ENETS) or the SEER databases, each with varying abilities to predict tumour behaviour.\textsuperscript{6-11} To facilitate comparison in the present study we use a single, simplified staging system.
comparable to that used by SEER, documenting local, regional and distant disease among the different tumour sites.

**Presentation**

The mean patient age was 59 (range 12–92) years, and half the patients were men (Table 1). Nearly half the patients (48%) presented with localized disease. There was evidence of carcinoid syndrome in 12% of cases. The most common tumour location was the small bowel (48%), followed by the colon or rectum, appendix and stomach. Of all the patients in the study 74% had surgery (Table 1).

The presentation of disease varied depending on the stage of disease. For patients with localized disease, 31% were identified from endoscopy, imaging, or incidental finding at the time of laparotomy for some other indication. The next most common presentations were suspected appendicitis (21%), abdominal pain not yet diagnosed (17%) and GI bleeding or anemia (10%). In the remaining 17% of cases we could not determine the inciting clinical factor that led to the diagnosis. For patients with regional disease, the most common presentation was abdominal pain (47%) followed by GI obstruction (36%), incidental finding (12%) and GI bleed or anemia (10%). Patients with metastatic disease most commonly presented with abdominal pain (55%), carcinoid syndrome (33%), GI obstruction (28%), incidental finding (13%) and GI bleed or anemia (6%).

**Treatment**

Most patients had surgery as part of their treatment, whereas 25% ($n = 128$) of the patients did not. Treatment by surgery varied according to the extent of disease at presentation; 70% of patients with localized disease, 99% of patients with regional disease and 65% of patients with distant metastases had surgery. Most patients treated with surgery had only 1 surgery ($n = 387$), whereas 40 patients had 2 surgeries and 3 patients had 3 surgeries. The rate of R0 resections among first surgical procedures was 62% compared with 45% for second surgical procedures and 33% for third surgical procedures. Of the patients who did not have surgery, 58% ($75$ of $128$) had endoscopic removal of their tumour, representing type 1 and 2 gastric NETs and rectal NETs. In the group of patients who did not have either surgery or endoscopic removal of their primary tumour ($n = 64$), 92% presented with distant disease. Radionuclide therapy was given to a subset ($n = 90$) of patients who presented with metastatic disease or progressed to distant disease.

**Survival**

Patients were followed for on average 76 months. Table 2 shows the aggregate 5-year OS and DSS. Survival rates were calculated for the different groups according to stage, age, sex and tumour site.

### Table 1. Demographic and clinical characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex</td>
<td>267 (50)</td>
</tr>
<tr>
<td>Age, mean (range), yr</td>
<td>59 (12–92)</td>
</tr>
<tr>
<td>Stage at diagnosis</td>
<td></td>
</tr>
<tr>
<td>Localized</td>
<td>257 (48)</td>
</tr>
<tr>
<td>Regional</td>
<td>104 (20)</td>
</tr>
<tr>
<td>Metastatic</td>
<td>163 (32)</td>
</tr>
<tr>
<td>Missing/unknown</td>
<td>6 (1)</td>
</tr>
<tr>
<td>Carcinoid syndrome at presentation</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>62 (12)</td>
</tr>
<tr>
<td>No</td>
<td>426 (80)</td>
</tr>
<tr>
<td>Missing</td>
<td>41 (7)</td>
</tr>
<tr>
<td>Anatomic distribution</td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>45 (9)</td>
</tr>
<tr>
<td>Small bowel</td>
<td>293 (55)</td>
</tr>
<tr>
<td>Duodenum</td>
<td>15 (3)</td>
</tr>
<tr>
<td>Jejunum</td>
<td>13 (2)</td>
</tr>
<tr>
<td>Ileum</td>
<td>156 (29)</td>
</tr>
<tr>
<td>Small bowel NOS</td>
<td>109 (20)</td>
</tr>
<tr>
<td>Appendix</td>
<td>95 (17)</td>
</tr>
<tr>
<td>Colorectal</td>
<td>97 (19)</td>
</tr>
<tr>
<td>Right colon</td>
<td>25 (5)</td>
</tr>
<tr>
<td>Left colon</td>
<td>2 (0.5)</td>
</tr>
<tr>
<td>Sigmoid colon</td>
<td>4 (1)</td>
</tr>
<tr>
<td>Colon NOS</td>
<td>6 (1)</td>
</tr>
<tr>
<td>Rectal</td>
<td>60 (11)</td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>401 (74)</td>
</tr>
<tr>
<td>No</td>
<td>128 (25)</td>
</tr>
<tr>
<td>No data</td>
<td>1 (&lt; 1)</td>
</tr>
<tr>
<td>Radioisotope therapy</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>86 (17)</td>
</tr>
<tr>
<td>No</td>
<td>434 (83)</td>
</tr>
<tr>
<td>No data</td>
<td>10 (2)</td>
</tr>
</tbody>
</table>

*No data* = not otherwise specified.

### Table 2. Five-year overall and disease-specific survival

<table>
<thead>
<tr>
<th>Variable</th>
<th>5-year OS, %</th>
<th>5-year DSS, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Localized</td>
<td>81</td>
<td>97</td>
</tr>
<tr>
<td>Regional</td>
<td>78</td>
<td>90</td>
</tr>
<tr>
<td>Metastatic</td>
<td>51</td>
<td>58</td>
</tr>
<tr>
<td>Age, yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 50</td>
<td>64</td>
<td>79</td>
</tr>
<tr>
<td>&lt; 50</td>
<td>86</td>
<td>91</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>69</td>
<td>85</td>
</tr>
<tr>
<td>Female</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>70</td>
<td>89</td>
</tr>
<tr>
<td>Small bowel</td>
<td>70</td>
<td>83</td>
</tr>
<tr>
<td>Appendix</td>
<td>84</td>
<td>94</td>
</tr>
<tr>
<td>Colon</td>
<td>73</td>
<td>80</td>
</tr>
<tr>
<td>Rectum</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

DSS = disease-specific survival; OS = overall survival.
sex, anatomic distribution and whether or not surgery was performed. It is clear that for our cohort, increasing age but not sex was linked to poor outcomes, regardless of grade. On univariate analysis patients with metastatic disease had poorer outcomes for both OS and DSS (Table 3). For OS, there were significant differences on both univariate and multivariate analysis (Table 4). Patients older than 50 years were nearly 6 times as likely to die from any cause as patients younger than 50 years (Table 4). Sex, however, was not a factor in OS. Using NETs of the small bowel as a reference point, we found that patients with appendiceal and rectal tumours had significantly improved OS on univariate analysis, but the survival difference did not persist on multivariate analysis. Younger age was associated with improved disease-specific outcomes (Table 5). In addition, on multivariate analysis, men were less likely to die from their disease than women, and this was a significant deviation from the results seen for OS. For completeness, we examined patient outcomes comparing type 1 and 2 gastric NETs (n = 36) with type 3 (n = 9) to reveal that poor outcomes are almost solely attributable to patients with type 3 tumours.

**Response to treatment**

In our cohort surgical intervention was associated with improved OS and DSS by both univariate and multivariate analysis (Table 4, Table 5). When we looked at individual groups, surgery for localized tumours did not confer a DSS (p = 0.35) or OS benefit (p = 0.62) on multivariate analysis. The resection margins, whether R0, R1 or R2, did not appear to impact DSS for patients undergoing surgery for localized (p = 0.20) disease. All patients with regional disease had surgery, thus there was no comparator for analysis. Patients with distant disease who underwent surgery demonstrated significantly improved outcomes (Fig. 1). If the surgeon was able to obtain an R0 resection, 92% of patients survived 5 years; for R1 resections the DSS was 75% and for R2 resections it was 48%. This survival difference based on margin status was significant (p = 0.009).

We also examined survival for patients receiving radioisotope therapy. Patient selection for radioisotope therapy included patients with symptomatic disease, those unable to undergo surgery owing to comorbidities and those with

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**Table 3. Five-year univariate survival analysis comparing stage**

<table>
<thead>
<tr>
<th>Survival; stage</th>
<th>HR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall survival</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Localized</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Regional</td>
<td>1.2 (0.8–2.5)</td>
<td>0.38</td>
</tr>
<tr>
<td>Metastatic</td>
<td>2.9 (2.0–4.2)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disease-specific survival</th>
<th>HR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localized</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Regional</td>
<td>2.7 (0.9–8.4)</td>
<td>0.08</td>
</tr>
<tr>
<td>Metastatic</td>
<td>18.8 (7.6–46.8)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

**Table 4. Univariate and multivariate analyses of 5-year overall survival**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate analysis</th>
<th>Multivariate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95% CI)</td>
<td>p value</td>
</tr>
<tr>
<td>Age &gt; 50 yr</td>
<td>5.7 (2.2–10.0)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Sex, male v. female</td>
<td>1.0 (0.7–1.4)</td>
<td>0.94</td>
</tr>
<tr>
<td>Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach v. small bowel</td>
<td>0.6 (0.2–2.6)</td>
<td>0.54</td>
</tr>
<tr>
<td>Appendix v. small bowel</td>
<td>0.3 (0.2–0.6)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Colon v. small bowel</td>
<td>0.9 (0.5–1.6)</td>
<td>0.70</td>
</tr>
<tr>
<td>Rectum v. small bowel</td>
<td>0.5 (0.3–0.9)</td>
<td>0.048</td>
</tr>
<tr>
<td>Surgery, yes v. no</td>
<td>0.5 (0.3–0.7)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

**Table 5. Univariate and multivariate analyses of 5-year disease-specific survival**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate analysis</th>
<th>Multivariate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95% CI)</td>
<td>p value</td>
</tr>
<tr>
<td>Age &gt; 50 yr</td>
<td>5.2 (2.4–11.3)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Sex, male v. female</td>
<td>0.7 (0.4–1.0)</td>
<td>0.06</td>
</tr>
<tr>
<td>Site</td>
<td></td>
<td></td>
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<tr>
<td>Stomach v. small bowel</td>
<td>0.5 (0.2–1.2)</td>
<td>0.12</td>
</tr>
<tr>
<td>Appendix v. small bowel</td>
<td>0.2 (0.05–0.5)</td>
<td>0.003</td>
</tr>
<tr>
<td>Colon v. small bowel</td>
<td>1.2 (0.6–2.4)</td>
<td>0.54</td>
</tr>
<tr>
<td>Rectum v. small bowel</td>
<td>0.6 (0.2–1.3)</td>
<td>0.17</td>
</tr>
<tr>
<td>Surgery, yes v. no</td>
<td>0.3 (0.2–0.5)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

**Table 4. Univariate and multivariate analyses of 5-year overall survival**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate analysis</th>
<th>Multivariate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95% CI)</td>
<td>p value</td>
</tr>
<tr>
<td>Age &gt; 50 yr</td>
<td>5.7 (2.2–10.0)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Sex, male v. female</td>
<td>1.0 (0.7–1.4)</td>
<td>0.94</td>
</tr>
<tr>
<td>Site</td>
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<td>Stomach v. small bowel</td>
<td>0.6 (0.2–2.6)</td>
<td>0.54</td>
</tr>
<tr>
<td>Appendix v. small bowel</td>
<td>0.3 (0.2–0.6)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Colon v. small bowel</td>
<td>0.9 (0.5–1.6)</td>
<td>0.70</td>
</tr>
<tr>
<td>Rectum v. small bowel</td>
<td>0.5 (0.3–0.9)</td>
<td>0.048</td>
</tr>
<tr>
<td>Surgery, yes v. no</td>
<td>0.5 (0.3–0.7)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

**Table 5. Univariate and multivariate analyses of 5-year disease-specific survival**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate analysis</th>
<th>Multivariate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR (95% CI)</td>
<td>p value</td>
</tr>
<tr>
<td>Age &gt; 50 yr</td>
<td>5.2 (2.4–11.3)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Sex, male v. female</td>
<td>0.7 (0.4–1.0)</td>
<td>0.06</td>
</tr>
<tr>
<td>Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach v. small bowel</td>
<td>0.5 (0.2–1.2)</td>
<td>0.12</td>
</tr>
<tr>
<td>Appendix v. small bowel</td>
<td>0.2 (0.05–0.5)</td>
<td>0.003</td>
</tr>
<tr>
<td>Colon v. small bowel</td>
<td>1.2 (0.6–2.4)</td>
<td>0.54</td>
</tr>
<tr>
<td>Rectum v. small bowel</td>
<td>0.6 (0.2–1.3)</td>
<td>0.17</td>
</tr>
<tr>
<td>Surgery, yes v. no</td>
<td>0.3 (0.2–0.5)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>
disease that was not amenable to resection. Radioisotope therapy appears to impact OS on multivariate analysis (Fig. 2). Moreover, as the number of radioisotope therapies for a given patient increased, we observed improved OS with a hazard ratio of 0.84 ($p < 0.001$) and improved DSS with a hazard ratio of 0.83 ($p = 0.001$). Finally, we examined systemic octreotide therapy, which was given to nearly 1 in 5 patients ($n = 99$) primarily to treat symptoms of serotonin excess. We observed a small but significant improvement in survival (Fig. 3).

DISCUSSION

The overall incidence of NETs in our centre has increased significantly from 11 per million to 19 per million over a 15-year period. Our results are concordant with those of other North American centres as well as with those of studies completed in Europe, where the incidence of GI NETs is rising. At least part of this increase is likely due to the increased access and use of cross-sectional imaging for investigation of abdominal presentations, but the true prevalence remains unknown. The anatomic distribution of NETs in our study reflects that seen in other studies, with small bowel and appendical tumours accounting for more than two-thirds of all GI NETs. Our average age and equal incidence between men and women are generally concordant with studies performed worldwide. With respect to advancing stage and patient age, our results were similar to those published previously in terms of decreased survival. One of the novel findings of our study was that we did not see a sex bias in survival favouring women, as has been outlined by previous reports. In fact, male sex was associated with improved DSS (HR = 0.6, $p = 0.014$) on multivariate analysis.

We demonstrate potential value to surgical intervention in this challenging and complex group of patients. Surgery, both curative and palliative, is associated with a decreased risk of overall and disease-specific death by multivariate analysis. Surgical treatments of distant disease were associated with improved survival, where 5-year DSS for R0 resections was nearly double that for patients with macroscopic disease. As with many surgical studies, there is likely a selection bias to explain the association between surgery and improved survival, as patients with advanced metastatic disease and/or multiple comorbidities are less often candidates for surgery. However, we note that the most significant survival benefit associated with surgery was observed in patients with advanced disease. In addition, there was an association between R0 status and improved disease-specific outcomes ($p = 0.009$). Our evidence is concordant with that of other authors who documented improved outcomes with surgery for metastatic disease.

The survival rate in our study for R0 resections is higher than that reported in other studies (55%–80%). We attribute this improvement, in part, to the use of postoperative radioisotope therapy to minimize the
Risk of recurrence and control tumour growth. More than one-third of patients with distant disease received radioisotope therapy. Thus, our work further confirms that multimodality efforts anchored with surgery may go beyond symptom relief and may in fact improve OS and DSS.

Radioisotope therapy may be used to control symptoms, but it may also translate into improved outcomes for patients with distant disease. The most significant impact of radiopharmaceutical therapy was identified in those patients given multiple doses, likely reflecting avidity and improved efficacy. To our knowledge there is no level 1 evidence to suggest that radiotherapy has a survival benefit, although a small, nonrandomized study by Nguyen and colleagues documented improved survival for patients with metastatic NETs. In addition, a retrospective review by Sywak and colleagues showed improved 5-year OS when radioisotope therapy was used to treat metastatic midgut NETs. The survival benefit was most pronounced at 3 and 5 years. These studies suggest a combined role for surgery and radioisotope therapy for patients with metastatic NETs. The complexity of NETs in terms of origin, metastatic potential and variations in disease avidity for radioisotope therapy make performing large, prospective randomized trials difficult. Although the use of long-acting octreotide in this cohort was intended to treat carcinoid symptoms, we also saw a small improvement in survival overall, and there is recent evidence supporting its use to improve survival. Clearly, there is much more work needed to demonstrate the relative contributions of multimodal therapy to outcomes of patients with GI NETs.

**Conclusion**

In this population study of NETs, we report a significant increase in the incidence of disease. Surgery, both curative and palliative, was associated with decreased risk of overall (HR = 0.6, p = 0.004) and disease-specific death (HR = 0.5, p < 0.001) on univariate and multivariate analysis. Patients with distant disease were nearly twice as likely as patients with residual macroscopic disease to survive 5 years if they had R0 resections. The use of radioisotope therapy was also associated with improved outcomes overall. Advancing disease stage and patient age, but not male sex, were associated with poor outcomes in terms of OS and DSS.

**Affiliations:** From the Division of General Surgery, University of Alberta, Edmonton, Alta. (McMullen, de Gara, Schiller); the Division of Pediatric Surgery, University of Dammam, Saudi Arabia (Al-Jahdali); the Department of Biostatistics and Epidemiology, Cross Cancer Institute, Edmonton, Alta. (Ghosh); and the Department of Oncologic Imaging, Cross Cancer Institute, Edmonton, Alta. (McEwan).

**Competing interests:** T. McMullen is a paid consultant with Galapagos LLC and has received speaker fees from Novartis. No other competing interests declared.

**Contributors:** T. McMullen, C. de Gara and D. Schiller designed the study. T. McMullen and A. Al-Jahdali acquired and analyzed the data, which S. Ghosh, A. McEwan and D. Schiller also analyzed. T. McMullen wrote the article, which all authors reviewed and approved for publication.

**References**

Comparison of outcomes of root replacement procedures and supracoronary techniques for surgical repair of acute aortic dissection

Background: Surgical approach to type A acute aortic dissection (AADA) is usually dictated by the presenting anatomy. We compared long-term outcomes of AADA repaired with a root replacement versus a supracoronary tube graft, regardless of the proximal extent of the intimal tear.

Methods: A single-centre, retrospective cohort of consecutive patients undergoing repair of AADA between December 1999 and March 2012 were stratified based on the proximal surgical procedure performed: supracoronary tube graft or root replacement. Imaging, chart reviews and clinical follow-ups were analyzed to identify the presenting anatomy and clinical outcomes.

Results: We included the cases of 75 patients in our analysis: 54 received a supracoronary tube graft and 21 received a root replacement. The proximal tear was identified below the sinotubular junction in all patients in the root group and in 61% of patients in the supracoronary group. We detected no differences between the groups for in-hospital mortality, length of stay, or complications. However, the root group had significantly increased renal failure (0% v. 9.5%, \( p = 0.018 \)), cardiopulmonary bypass time (198.4 ± 80.0 min v. 316.5 ± 102.5 min, \( p < 0.001 \)), cross-clamp time (91.6 ± 34.9 min v. 191.3 ± 52.8 min, \( p < 0.001 \)), duration of surgery (457.5 ± 129.9 min v. 611.6 ± 197.8 min, \( p < 0.001 \)), and platelet transfusions (8.1 ± 7.6 v. 12.8 ± 8.7 units, \( p = 0.021 \)) than the supracoronary group. Long-term follow-up demonstrated a greater incidence of 2+ aortic regurgitation among patients in the supracoronary group than the root group (29.7% v. 0.0%, \( p = 0.006 \)); however, there was no difference between the groups in symptoms or reoperation.

Conclusion: In AADA, aortic root replacement involves a longer procedure with increased risk of early renal impairment. Long-term follow-up identified significantly more aortic regurgitation and root dilation in the supracoronary group than the root group, with a trend toward worse long-term survival. However, we found no difference between the groups in mortality, reoperation or New York Heart Association class.

Contexte : L’approche chirurgicale à la dissection aigüe de l’aorte de type A (DAAA) dépend habituellement de la présentation anatomique. Nous avons comparé les résultats à long terme d’une DAAA réparée par remplacement de la racine de l’aorte c. greffon supracoronarien artificiel, indépendamment de la portée proximale de la déchirure de l’intima.

Méthodes : Une cohorte rétrospective monocentrique de patients consécutifs soumis à une réparation de DAAA entre décembre 1999 et mars 2012 a été stratifiée en fonction de l’intervention chirurgicale proximale effectuée : greffon supracoronarien artificiel ou remplacement de la racine de l’aorte. Les épreuves d’imagerie, résumés de dossiers et suivis cliniques ont été analysés pour cerner la présentation anatomique et les résultats cliniques.

Résultats : Nous avons inclus 75 patients dans notre analyse : 54 ont reçu un greffon supracoronarien artificiel et 21 ont subi un remplacement de la racine de l’aorte. Une déchirure proximale a été identifiée sous la jonction sinotubulaire chez tous les patients du groupe racine de l’aorte et chez 61 % des patients du groupe greffon supracoronarien. Nous n’avons observé aucune différence entre les groupes pour ce qui est de la mortalité en milieu hospitalier, de la durée de l’hospitalisation ou des complications. Mais, le groupe racine de l’aorte a présenté des augmentations significatives du nombre de cas d’insuffisance rénale (0 % c. 9.5 %, \( p = 0.018 \)), de la durée
de la circulation extracorporelle (198,4 ± 80,0 min c. 316,5 ± 102,5 min, p < 0,001),
du clampage de l’aorte (91,6 ± 34,9 min c. 191,3 ± 52,8 min, p < 0,001) et de la
chirurgie (457,5 ± 129,9 min c. 611,6 ± 197,8 min, p < 0,001), ainsi que du nombre de
transfusions plaquettaires (8,1 ± 7,6 unités c. 12,8 ± 8,7 unités, p = 0,021) compara-
tivement au groupe greffon supracoronarien. Le suivi à long terme a fait état d’une
incidence plus élevée de régurgitation aortique 2+ chez les patients du groupe gref-
one supracoronarien comparativement au groupe racine de l’aorte (29,7 % c. 0,0 %,
p = 0,006); toutefois, on n’a noté aucune différence entre les groupes pour ce qui est
des symptômes ou du taux de réopération.

**Conclusion** : Dans la DAAA, le remplacement de la racine de l’aorte suppose une
intervention de plus longue durée qui s’accompagne d’un risque accru d’insuffisance
renale précoce. Un suivi à long terme a révélé un nombre significativement plus élevé
de cas de régurgitation aortique et de dilatation de la racine de l’aorte dans le groupe
greffe supracoronarien que dans le groupe racine de l’aorte, avec une tendance
moins favorable au plan de la survie à long terme. Toutefois, nous n’avons trouvé
aucune différence entre les groupes pour ce qui est de la mortalité, du taux de
réopération ou de la classe de la New York Heart Association.

**Methods**

**Patient population**

We retrospectively reviewed the charts, imaging and operative reports of consecutive patients who underwent aortic surgery for AADA at the University Hospital of the Lon-
don Health Sciences Centre in London, Ont., between December 1999 and March 2012 to identify the presenting anatomy (proximal/distal extent of dissection, previous
aneurysm, bicuspid valve), presence of risk factors for aortic dissection (hypertension, family history, connective tissue disorder, cocaine use, pregnancy) and operative procedure performed. Approval for data collection for this study was
granted by the research ethics board of Western University, which waived the requirement for individual patient con-
sent. All patients underwent preoperative CT of the thorax,
confirming diagnosis of type A dissection, and had intra-
operative transesophageal echocardiography.

Patients were retrospectively classified into 2 groups
based on the surgical details provided in the operative
report. The supracoronary group included all patients
who underwent repair with a supracoronary tube graft,
with or without resuspension of the aortic valve commis-
sures (Fig. 1). The root group included patients who
underwent either a composite valve graft replacement or
aortic valve-sparing procedure (Fig. 1).

**Surgical technique**

All procedures occurred under the discretion of 1 of 8 par-
ticipating surgeons, resulting in variations among cannula-
tion site, degree of hypothermia, cardioplegia protection
strategy and cerebral perfusion technique. Standard post-
operative protocols were followed for immediate postsur-
gical care and ward convalescence.

In the supracoronary group, some patients had an aortic
entry tear clearly identified distal to the sinotubular junc-
tion, and the aortic root and valve along with the coronary

**Stanford type A acute aortic dissection (AADA)** is a
lethal condition with an early mortality of 1% per
hour and 21% in first 24 hours with isolated med-
ical therapy.\(^2\) Surgical considerations include deciding
on the proximal and distal degree of the resection, excluding
the intimal tear, removing diseased/aneurysmal tissue and
preventing malperfusion.\(^2\)\(^3\) Proximal extension of an
AADA into the aortic root (below the sinotubular junc-
tion) has important implications for the degree of com-
plexity required for adequate repair.\(^3\)\(^4\) Aortic root proced-
ures involving composite valve grafts or valve-sparing
techniques while excluding the proximal intimal tear are
presumed to be technically challenging because of the
complexity of reimplanting coronary arteries, requirement
of additional suture lines, and extended cardiopulmonary
bypass and cross-clamp durations.\(^4\) Using a supracorono-
tary tube graft (with or without commissural resuspension) to
replace the ascending aorta and exclude the entry tear that
is below the sinotubular junction but not involving the
aortic annulus can be performed as a more conservative
alternative.\(^5\) Restoration of the association between the
size of the aortic root and ascending aorta along with
resuspension of commissures has been demonstrated to be
adequate to address the acute aortic insufficiency associ-
ated with AADA.\(^6\)

Many factors, including patient comorbidities, presence
or absence of connective tissue disorder, morphology of
the aortic valve and the extent of the proximal tear into the
aortic root, contribute to the surgical decision-making
regarding the need for a total root replacement compared
with a more conservative supracoronary graft.\(^7\) The pur-
pose of the present study was to report patient demo-
graphic characteristics, operative outcomes (mortality and
major adverse cardiac events), clinical follow-up (survival
and freedom from reoperation) and imaging (echocardiog-
raphy and computed tomography [CT]) results of patients
presenting with AADA who were treated with root
replacement procedures compared with a conservative
approach for root intervention.

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lethal condition with an early mortality of 1% per
hour and 21% in first 24 hours with isolated med-
ical therapy.\(^2\) Surgical considerations include deciding
on the proximal and distal degree of the resection, excluding
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tion) has important implications for the degree of com-
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ures involving composite valve grafts or valve-sparing
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alternative.\(^5\) Restoration of the association between the
size of the aortic root and ascending aorta along with
resuspension of commissures has been demonstrated to be
adequate to address the acute aortic insufficiency associ-
ated with AADA.\(^6\)

Many factors, including patient comorbidities, presence
or absence of connective tissue disorder, morphology of
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aortic root, contribute to the surgical decision-making
regarding the need for a total root replacement compared
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graphic characteristics, operative outcomes (mortality and
major adverse cardiac events), clinical follow-up (survival
and freedom from reoperation) and imaging (echocardiog-
raphy and computed tomography [CT]) results of patients
presenting with AADA who were treated with root
replacement procedures compared with a conservative
approach for root intervention.
artery ostia were not involved. Most patients in this group, had dissections where the entry tear, or the dissection flap, extended below the sinotubular junction, but not into the annulus. For patients in the root group, the decision was made by the individual surgeon in the operating room to proceed with complete replacement of the root with reimplantation of the coronary arteries in order to address the competency of the valve and native architecture of the root as the entry tear was below the level of the sinotubular junction. One patient required conversion from a supracoronary tube graft to a composite valve graft because of severe postrepair aortic insufficiency (AI).

Clinical and imaging follow-up

We completed a retrospective chart review and assessment of outcomes according to our institutional database for all patients. Transthoracic echocardiography assessed postoperative aortic regurgitation, degree of aortic root dilation and ventricular function. Postoperative CT evaluated aortic root dilation, patency of distal false lumen and presence of sternal wound infection or dehiscence.

Statistical analysis

Continuous variables are expressed as means ± standard deviations, and categorical data are expressed as percentages. We compared categorical variables using $\chi^2$ tests and independent continuous variables using unpaired Student t tests. We considered results to be significant at $p < 0.05$.

RESULTS

Preoperative demographic characteristics

Of the 75 patients undergoing surgical repair of an acute type A aortic root dissection during our study period, 54 were treated with a supracoronary tube graft with or without commissural resuspension of the aortic valve and 21 were treated with a root replacement procedure. The demographic characteristics and presenting anatomy are displayed in Table 1 and Table 2. There was no significant difference between the groups in age; sex; prevalence of clinically important comorbidities, such as hypertension; previous myocardial infarction (MI); previous cardiac surgery; or urgency of the procedure. The presenting anatomy of the aortic dissections is described in Table 2. Thirty-three of the 54 patients in the supracoronary group compared with all patients in the root group had dissections that were identified as proximal to the sinotubular junction (61.1% v. 100%, $p < 0.001$). There was no significant difference between the groups with respect to involvement of the aortic arch or descending aorta; presence of a bicuspid valve; or presence of hypertension, family history, current pregnancy, or illicit drug use.

![Fig. 1. Intraoperative images of acute type A aortic dissection (left), with post-Bentall repair, involving complete replacement of the aortic root with reimplantation of coronary buttons and ascending aortic Dacron tube graft (right).](image-url)
drug use. Presence of connective tissue disorder was significantly higher in the root group than the supracoronary group (1.9% v. 14.2%, p = 0.018).

Operative results

There was no significant difference between the groups in 30-day mortality (20.4% in the supracoronary group v. 19.0% in the root group). Major adverse cardiac events, including postoperative infection, renal failure, ventilator dependence, need for reoperation for bleeding and dehiscence, did not differ significantly between the groups. Operative details and results are shown in Table 3. There was no significant difference between the groups in location of arterial cannulation (femoral, axillary or both). Cardiopulmonary bypass time (198.4 ± 80.0 min v. 316.5 ± 102.5 min, p < 0.001), cross-clamp time (91.6 ± 34.9 min v. 191.3 ± 52.8 min, p < 0.001) and total operating room time (457.5 ± 129.9 min v. 611.6 ± 197.8 min, p < 0.001), were all significantly increased for patients undergoing a root replacement procedure. Degree of hypothermia, presented as the average of the coolest operative temperatures, did not differ significantly between the groups (21.9 ± 4.7°C in the supracoronary group v. 21.0 ± 3.2°C in the root group).

Table 1. Demographic and clinical characteristics of the study sample

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (n = 75)</th>
<th>Supracoronary graft (n = 54)</th>
<th>Root procedure (n = 21)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>63.3 ± 13.7</td>
<td>63.9 ± 13.4</td>
<td>61.4 ± 14.8</td>
<td>0.48</td>
</tr>
<tr>
<td>Male sex</td>
<td>40 (53.3)</td>
<td>37 (68.5)</td>
<td>13 (61.9)</td>
<td>0.58</td>
</tr>
<tr>
<td>Hypertension</td>
<td>43 (57.3)</td>
<td>31 (57.4)</td>
<td>12 (57.1)</td>
<td>0.98</td>
</tr>
<tr>
<td>Emergent procedure*</td>
<td>57 (76.0)</td>
<td>41 (75.9)</td>
<td>16 (76.2)</td>
<td>0.98</td>
</tr>
<tr>
<td>Salvage procedure†</td>
<td>12 (16.0)</td>
<td>9 (16.7)</td>
<td>3 (14.3)</td>
<td>0.80</td>
</tr>
<tr>
<td>Previous cardiac surgery</td>
<td>8 (10.7)</td>
<td>5 (9.3)</td>
<td>3 (14.3)</td>
<td>0.52</td>
</tr>
<tr>
<td>Previous MI</td>
<td>1 (1.9)</td>
<td>1 (1.9)</td>
<td>0 (0)</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Table 2. Presenting anatomy

<table>
<thead>
<tr>
<th>Anatomy</th>
<th>Total (n = 75)</th>
<th>Supracoronary graft (n = 54)</th>
<th>Root procedure (n = 21)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root involvement</td>
<td>54 (72.0)</td>
<td>33 (61.1)</td>
<td>21 (100)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Arch repaired*</td>
<td>16 (21.3)</td>
<td>10 (18.5)</td>
<td>6 (28.6)</td>
<td>0.34</td>
</tr>
<tr>
<td>Bicuspid valve</td>
<td>1 (1.3)</td>
<td>0 (0)</td>
<td>1 (4.7)</td>
<td>0.11</td>
</tr>
<tr>
<td>Tricuspid valve</td>
<td>74 (98.7)</td>
<td>54 (100)</td>
<td>20 (95.3)</td>
<td>0.11</td>
</tr>
<tr>
<td>Connective tissue disorder</td>
<td>4 (5.3)</td>
<td>1 (1.9)</td>
<td>3 (14.2)</td>
<td>0.18</td>
</tr>
<tr>
<td>Risk factors†</td>
<td>50 (66.7)</td>
<td>34 (63.3)</td>
<td>16 (76.2)</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Table 3. Operative characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (n = 75)</th>
<th>Supracoronary graft (n = 54)</th>
<th>Root procedure (n = 21)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral cannulation</td>
<td>38 (50.7)</td>
<td>30 (55.6)</td>
<td>8 (38.1)</td>
<td>0.18</td>
</tr>
<tr>
<td>Axillary cannulation</td>
<td>16 (21.3)</td>
<td>12 (22.2)</td>
<td>4 (19.0)</td>
<td>0.76</td>
</tr>
<tr>
<td>Femoral and axillary cannulation</td>
<td>13 (17.3)</td>
<td>9 (16.7)</td>
<td>4 (19.0)</td>
<td>0.36</td>
</tr>
<tr>
<td>Total operative duration</td>
<td>494.6 ± 162.3</td>
<td>457.5 ± 129.9</td>
<td>611.6 ± 197.8</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Cardiopulmonary bypass time, min</td>
<td>229.2 ± 100.8</td>
<td>196.4 ± 80.0</td>
<td>316.5 ± 102.5</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Aortic cross-clamp time, min</td>
<td>118.8 ± 60.2</td>
<td>91.6 ± 34.9</td>
<td>191.3 ± 52.8</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Lowest core temperature, °C</td>
<td>21.7 ± 4.4</td>
<td>21.9 ± 4.7</td>
<td>21.0 ± 3.2</td>
<td>0.42</td>
</tr>
</tbody>
</table>

SD = standard deviation.

MI = myocardial infarction; SD = standard deviation.

*Emergent procedures refer to high-acuity surgical case taken to the operating room within 2 h of original presentation to hospital.
†Salvage procedures occurred in patients in cardiogenic shock requiring inotropic or mechanical support.
root group, \( p = 0.42 \)). There was no significant difference in the rates of packed red blood cell transfusion (9.2 ± 8.9 units v. 11.5 ± 8.4 units, \( p = 0.31 \)) or fresh frozen plasma (10.7 ± 9.9 units v. 14.2 ± 10.4 units, \( p = 0.18 \)) between the supracoronary and root groups; however, we found a significant difference in the rates of platelets transfused (8.1 ± 7.6 units v. 12.8 ± 8.7 units, \( p = 0.021 \)).

**Postoperative imaging follow-up results**

Postoperative imaging data were available for 34 of 43 (79.1%) patients in the supracoronary group who survived beyond 30 days postoperatively; their mean duration of follow-up was 84.7 ± 53.1 months. These data were available for 16 of the 17 (94.1%) patients in the root group who survived beyond 30 days postoperatively; their mean duration of follow-up was 70.3 ± 34.0 months. The degree of aortic regurgitation was evaluated at follow-up, with yearly transthoracic echocardiography. Significant regurgitation was deemed to be greater than 2+ to account for any interevaluator bias, as different cardiologists were reviewing the patients’ charts. Patients in the supracoronary group had a greater incidence of 2+ aortic regurgitation than patients in the root group (29.7% v. 0.0%, \( p = 0.006 \); Table 4). Of the patients in the supracoronary group who had an intimal dissection flap proximal to the sinotubular junction, 25.0% were found to have significant 2+ aortic regurgitation at the most recent follow-up.

Follow-up CT imaging identified a patent distal false lumen in 16.7% of patients in the supracoronary group and 23.8% in the root group (\( p = 0.48 \)). Furthermore, echocardiography and CT reports showed a significant enlargement of the aortic root in the supracoronary group compared with the root group (44 ± 6 mm v. 30 ± 5 mm, \( p = 0.002 \); Table 4).

**Clinical follow-up results**

Long-term clinical follow-up data were available for 86% of patients who survived beyond 30 days postoperatively. Overall survival at 1 and 5 years was 71.7% and 67.9%, respectively, in the supracoronary group and 70.6% and 70.6%, respectively, in the root group. Kaplan–Meier survival curves are displayed in Figure 2. No significant difference between the groups was seen on follow-up with regards to cardiac-related deaths, functional (New York Heart Association) status or need for reoperation in patients surviving beyond the first 30 postoperative days (Table 4).

### Table 4. Surgical outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Total (n = 75)</th>
<th>Supracoronary graft (n = 54)</th>
<th>Root procedure (n = 21)</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-hospital 30-day mortality</td>
<td>15 (20.0)</td>
<td>11 (20.4)</td>
<td>4 (19.0)</td>
<td>0.90</td>
</tr>
<tr>
<td>Stroke</td>
<td>2 (2.7)</td>
<td>0 (0)</td>
<td>2 (9.5)</td>
<td>0.018</td>
</tr>
<tr>
<td>Postoperative infection</td>
<td>2 (2.7)</td>
<td>1 (1.9)</td>
<td>1 (4.8)</td>
<td>0.48</td>
</tr>
<tr>
<td>Ventilator dependence</td>
<td>11 (14.7)</td>
<td>7 (13.0)</td>
<td>4 (19.0)</td>
<td>0.50</td>
</tr>
<tr>
<td>Reoperation for bleeding</td>
<td>9 (12.0)</td>
<td>7 (13.0)</td>
<td>2 (9.5)</td>
<td>0.68</td>
</tr>
<tr>
<td>Postoperative MI</td>
<td>1 (1.3)</td>
<td>0 (0)</td>
<td>1 (4.8)</td>
<td>0.11</td>
</tr>
<tr>
<td>Sternal dehiscence</td>
<td>2 (2.7)</td>
<td>1 (1.9)</td>
<td>1 (4.8)</td>
<td>0.48</td>
</tr>
<tr>
<td>Patent false lumen on CT</td>
<td>14 (18.7)</td>
<td>9 (16.7)</td>
<td>5 (23.8)</td>
<td>0.48</td>
</tr>
<tr>
<td>Aortic root, mm</td>
<td>38 ± 9</td>
<td>44 ± 6</td>
<td>30 ± 5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2+ aortic regurgitation</td>
<td>8 (20.0)</td>
<td>8 (20.7)</td>
<td>0 (0)</td>
<td>0.006</td>
</tr>
<tr>
<td>Transfusion outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packed red blood cells</td>
<td>9.8 ± 7.3</td>
<td>9.2 ± 8.9</td>
<td>11.5 ± 8.4</td>
<td>0.31</td>
</tr>
<tr>
<td>Adult platelets</td>
<td>9.3 ± 8.1</td>
<td>8.1 ± 7.6</td>
<td>12.8 ± 8.7</td>
<td>0.021</td>
</tr>
<tr>
<td>Fresh frozen plasma</td>
<td>11.6 ± 10.1</td>
<td>10.7 ± 9.9</td>
<td>14.2 ± 10.4</td>
<td>0.18</td>
</tr>
<tr>
<td>Patients not requiring transfusion</td>
<td>4 (5.4)</td>
<td>3 (5.7)</td>
<td>1 (4.8)</td>
<td>0.68</td>
</tr>
<tr>
<td>Cardiac-related deaths</td>
<td>18 (88.9)</td>
<td>13 (81.3)</td>
<td>5 (100)</td>
<td>0.35</td>
</tr>
<tr>
<td>Reoperation</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>&gt;0.99</td>
</tr>
<tr>
<td>NYHA class in living patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>29 (67.4)</td>
<td>22 (71.0)</td>
<td>7 (58.3)</td>
<td>0.56</td>
</tr>
<tr>
<td>II</td>
<td>9 (20.9)</td>
<td>5 (16.1)</td>
<td>4 (33.3)</td>
<td>0.28</td>
</tr>
<tr>
<td>III</td>
<td>5 (11.6)</td>
<td>4 (12.9)</td>
<td>1 (8.3)</td>
<td>0.60</td>
</tr>
<tr>
<td>IV</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>&gt;0.99</td>
</tr>
</tbody>
</table>

CT = computed tomography; ICU = intensive care unit; MI = myocardial infarction; NYHA = New York Heart Association; SD = standard deviation.
DISCUSSION

The results of our study suggest that in the setting of acute type A dissections, aortic root replacement procedures consisting of composite valve grafts or aortic valve-sparing techniques do not appear to expose patients to an increased risk of perioperative adverse outcomes, even given the significantly increased need for platelet transfusions, OR, total bypass and cross-clamp times, and resulted in long-term competency of the aortic valve.

Interestingly, more than 60% of the patients who received an isolated supracoronary tube graft still had a proximal tear identified below the sinotubular junction. This observation indicates that in reality the decision to address the aortic root at the time of surgery likely depends on other factors, including clinical status; tissue quality; and surgeon comfort with aortic root replacement procedures, such as composite valve grafts and aortic valve-sparing techniques, as they represent a far more technically demanding and lengthy procedure. However, we did not detect a significant difference in postoperative complications. Our series did not show any significant increase in major complications (death, stroke, bleeding requiring reoperation, MI, ventilator dependence, infection) among patients who underwent an aortic root replacement procedure. Furthermore, these procedures did not result in any significant increase in admissions to the intensive care unit or length of hospital stay. There was an increase in units of transfused platelets between the supracoronary and root groups (8.1 ± 7.6 units v. 12.8 ± 8.7 units, \( p = 0.021 \)); however, we felt this increase was likely due to the increased pump times leading to an expected increase in postoperative platelet dysfunction.

The mortality and morbidity results achieved in this study for root replacement procedures are similar to those reported in other studies. Our 30-day mortality of 20.0% is similar to that described by multiple trials involving the International Registry of Acute Aortic Dissection (IRAD) database, which reported mortality between 16.2% and 27.4%.8,9 As seen in the Kaplan–Meier survival curve in our study (Fig. 1.), although early mortality was high, patients surviving the perioperative period did well in the long term.

An additional important outcome from our study was the echocardiographic findings demonstrating that 29.7% of patients with supracoronary tube grafts and commissural resuspension experienced moderate to severe AI at a mean follow-up of 84.7 ± 55.1 months. We demonstrated a significant reduction of more than 2+ aortic regurgitation in patients who underwent a root procedure compared with those who underwent a supracoronary tube graft with or without commissural resuspension (0% v. 29.7%, \( p = 0.006 \)). Interestingly, there was no significant difference in development of aortic regurgitation within the supracoronary group between patients who had a proximal intimal tear within the root and those who did not (25.0% v. 29.7%). This finding may indicate that development of regurgitation in the future may be secondary only to the native tissue left behind if competency is restored to the aortic valve at the time of surgery. Our results differ from those of Ryški and colleagues,10 who studied the long-term echocardiography and CT results of 119 patients who
underwent a supracoronary tube graft for AADA. At median follow-up of 33.8 months, 26 (27%) patients had new-onset aortic root disease and 10 required aortic root reoperation. The data on patients in the root group in our study are more in line with the work of Leontyev and colleagues, who described a series of 179 patients undergoing root replacement procedures, none of whom had greater than 2+ AI at short-term follow-up and in whom 5-year freedom from reoperation was approximately 96%. Three patients in our cohort were identified on clinical follow-up to meet guidelines for reoperation owing to chronic aortic regurgitation or aortic root dilation. None of these patients received an aortic valve reoperation owing to advanced age or comorbidities; in these cases the surgeon deemed the operation too risky or the patient declined the operation. The survival curves and clinical outcome data presented here suggest that chronic AI in these patients, although clinically well tolerated, likely explains the decreased survival we observed when comparing the supracoronary with the root group over time. Rates of persistent false lumen flow in our study were comparable between the groups (16.7% in the supracoronary group v. 23.8% in the root group, p = 0.48); however, the rates were significantly lower than the 69% previously reported in the literature.

Our results demonstrate that aortic root procedures, including remodeling/reimplantation techniques and composite valve grafts, have comparable perioperative outcomes to supracoronary procedures despite exposing individuals to longer bypass times, more transfusions and a greater risk of renal failure. The real benefit of replacing the entire aortic root seems to emerge with time as individuals are faced with far fewer complications, such as chronic AI and root dilation, leading to improved survival trends. Supracoronary tube grafts offer a technically less difficult operative approach with good perioperative outcomes, regardless of the proximal extent of the intimal tear, but expose the patient to worsening AI, root dilation and worse survival long-term.

Limitations

Limitations of our study include its retrospective design, lack of blinding and randomization owing to the nature of the disease, a small sample population at a single centre and the heterogeneity of the surgical approach among multiple surgeons. Regardless, we did not note any significant difference between the groups in baseline demographic characteristics, which would indicate a sampling error.

Conclusion

Our results suggest that in patients with an acute type A dissection, there is no significant difference in early perioperative outcomes between a root replacement procedure and a supracoronary tube graft, regardless of the proximal extent of the intimal tear. However, the more aggressive root techniques resulted in decreased rates of greater than 2+ AI, aortic root dilation and improved survival trends on long-term follow-up. We suggest that these techniques may be even more beneficial in younger patients or in the presence of connective tissue disorders when the surgeon feels that root replacement is technically feasible.

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Competing interests: M. Chu has received speakers’ honoraria from Medtronic Canada, Edwards Life Sciences, Livanova, Symetis and Abbott. B. Kiaii is a consultant, speaker and proctor for Medtronic, Johnson & Johnson and Symetis. He has received honoraria and travel assistance from those companies for speaking at meetings and providing proctorship. No other competing interests declared.

Contributors: All authors designed the study. M. Valdis, C. Adams and L. Guo acquired and analyzed the data, which M. Chu also analyzed. M. Valdis, C. Adams and M. Chu wrote the article, which all authors reviewed and approved for publication.

References

A comparison of revisional and primary bariatric surgery

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Background: Revisional surgery is an important component of addressing weight regain and complications following primary bariatric surgery. Owing to provincial need and the complexity of this patient population, a specialized multidisciplinary revision clinic was developed. We sought to characterize patients who undergo revision surgery and compare their outcomes with primary bariatric surgery clinic data.

Methods: We completed a retrospective chart review of bariatric revision clinic patients compared with primary bariatric surgery patients from December 2009 to June 2014.

Results: We reviewed the charts of 2769 primary bariatric clinic patients, 886 of whom had bariatric surgery, and 534 revision bariatric clinic patients, 83 of whom had revision surgery. Fewer revision clinic patients underwent surgery than primary clinic patients (22% v. 32%). The mean preoperative body mass index (BMI) was 44.7 ± 9.5 in revision patients compared with 45.7 ± 7.6 in primary bariatric surgery patients. Most revision patients had a prior vertical banded gastroplasty (VBG; 48%) or a laparoscopic adjustable gastric band (LAGB; 24%). Bands were removed in 36% of all LAGB patients presenting to clinic. Of the 134 procedures performed in the revision clinic, 83 were bariatric weight loss surgeries, and 51 were band removals. Revision clinic patients experienced a significant decrease in BMI (from 44.7 ± 9.3 to 33.8 ± 7.5, \( p < 0.001 \)); their BMI at 12-month follow-up was similar to that of primary clinic patients (34.5 ± 7.0, \( p = 0.7 \)). Complications were significantly more frequent in revision patients than primary patients (41% v. 15%, \( p < 0.001 \)).

Conclusion: A bariatric revision clinic manages a wide variety of complex patients distinct from those seen in a primary clinic. Operative candidates at the revision clinic are chosen based on favourable medical, anatomic and psychosocial factors, keeping in mind the resource constraints of a public health care system.

Contexte : La chirurgie de révision est une intervention importante lors d’une reprise de poids ou lors de complications à la suite d’une chirurgie bariatrique primaire. Compte tenu des besoins provinciaux et de la complexité de cette population de patients, une clinique de révision multidisciplinaire spécialisée a été créée. Nous avons voulu caractériser les patients qui subissent une chirurgie de révision et comparer leurs résultats aux données de la clinique de chirurgie bariatrique primaire.

Méthodes : Nous avons procédé à un examen rétrospectif des dossiers des patients de la clinique de révision bariatrique par rapport aux patients ayant subi une chirurgie bariatrique primaire entre décembre 2009 et juin 2014.

Résultats : Nous avons examiné les dossiers de 2769 patients de la clinique bariatrique primaire, dont 886 avaient subi une chirurgie bariatrique, et 534 patients de la clinique de révision, dont 83 avaient subi une chirurgie de révision. Un moins grand nombre de patients de la clinique de révision ont subi une chirurgie comparativement aux patients de la clinique primaire (22 % c. 32 %). L’indice de masse corporelle (IMC) préopératoire moyen était de 44,7 ± 9,5 chez les patients de la clinique de révision, contre 45,7 ± 7,6 chez les patients ayant subi la chirurgie bariatrique primaire. La plupart des patients de la clinique de révision avaient déjà subi une gastroplastie verticale (48 %) ou une pose d’anneau gastrique ajustable par voie laparoscopique (24 %). Les anneau gastriques ont été retirés chez 36 % de tous les patients de ce dernier groupe s’étant présentés à la clinique. Parmi les 134 interventions effectuées à la clinique de révision, 83 étaient des chirurgies bariatriques (pour perte de poids) et 51 concernaient des retraits d’anneaux. Les patients de la clinique de révision ont obtenu une diminution significative de leur IMC (de 44,7 ± 9,3 à
Bariatric surgery is the only evidence-based sustainable solution for the management of severe obesity.\(^1,2\) Without bariatric surgery only 5% of adults with established obesity can maintain a healthy body weight.\(^3\) In addition to weight loss, surgery can also improve comorbidities, such as diabetes, hypertension, dyslipidemia and sleep apnea.\(^2\) However, on average 20% of patients will either fail to lose adequate weight (< 50% excess weight loss) or will regain weight after surgery.\(^4\) Similar to hip replacements and cardiac surgery, revisional surgery is one aspect of treatment necessary to manage refractory symptoms or surgical complications. More bariatric surgeons are adding revisional bariatric procedures to their existing practices.\(^5\) This is a complex patient group that requires case-by-case medical and surgical management.\(^6\) A dedicated revision clinic was created to accommodate private and medical tourists who have little or no aftercare for the management of their nutrition and complications.\(^7\)

A multidisciplinary approach is modeled after the primary clinic, which includes nurses, dieticians, psychologists and physicians. A specific “red flag” system is used by each discipline to screen out patients who would be unlikely to succeed with revision surgery. Red flag criteria include uncontrolled mental health issues, substance abuse, poor social supports, poor compliance and unrealistic goals.\(^7\) The objective of this study was to review all 5 years of patients since the inception of the clinic and compare the outcomes, patient populations and complications between the revision clinic and the primary clinic.

**METHODS**

A retrospective review was conducted of patients who entered the Adult Bariatric Surgery Revision Clinic between its inception in December 2009 and June 2014. We retrieved information on demographics, body mass index (BMI), comorbidities, clinic visits, previous surgeries and complications. We also reviewed the charts of patients in the primary Edmonton Adult Bariatric Specialty Clinic over the same time period. This study was completed with full approval from our institutional ethics review board. To enter the revision clinic, patients were required to have a history of bariatric surgery and imaging (at minimum upper gastrointestinal swallow study and esophagoduodenoscopy) to delineate anatomy before their first clinic appointment. Patients were evaluated by a multidisciplinary team, including a nurse, dietician and psychologist, for red flags.\(^7\) Surgical candidates were chosen based on the specific red flag system designed to identify patients who would be unlikely to benefit from further surgery. This conservative operating strategy mirrors that of the Centre of Excellence–accredited primary bariatric clinic. Surgical candidates also had to have anatomy amenable to operative correction. In our experience, patients who have anatomic abnormalities seen on imaging and have undergone several surgical procedures are likely to have adhesions or a more difficult operation, which may reduce the benefit:risk ratio of revisional surgery.

All surgeries in the revision clinic were carried out by a single revisional surgeon (C.D.G.). Details regarding the surgical techniques for both primary and revision surgeries have been published previously.\(^8\) Primarily open Roux-en-Y gastric bypass (ORYGB) was performed in our patient population. Differences between the laparoscopic and open techniques were subtle. A fundic resection was carried out to avoid the risk of ischemia, and the Roux limb was made retrocolic. Follow-up postoperatively occurred at 1, 3, 6 and 12 months.

**Statistical analysis**

All data were analyzed using STATA statistical software (Statacorp). Continuous variables (e.g., BMI and age) are presented as means ± standard deviations and were analyzed for statistical significance using Kruskal–Wallis and Wilcoxon signed-rank tests. Categorical variables were analyzed using \( \chi^2 \) and Fisher exact tests. Graphs were created using GraphPad Prism software version 5.0.

**RESULTS**

We reviewed 534 charts from the revision clinic and 2769 from the primary bariatric clinic for the same time period. Of the 534 revision clinic patients, 18 patients were incomplete referrals, 130 patients were lost to follow-up after only 1 visit and 250 patients were treated medically. The remaining 136 patients were surgical candidates; 117 of them had surgery, whereas the others refused surgery and their symptoms were managed in other ways. Patients lost
to follow-up were contacted by the clinic by phone, and these patients declined to return for more than 1 appointment. A large number of patients left the clinic after being considered inappropriate for surgery based on the red flag system (126 of 250, 50%) and did not want to pursue medical management. The primary clinic no longer follows patients who are not surgical candidates. Of the 2769 patients seen in the primary clinic, 886 patients had surgery, and the remaining 1883 patients were lost to follow-up or were not surgical candidates and were discharged.

Demographic comparisons between the primary and revision clinic are shown in Table 1. Patients were significantly older in the revision group than in the primary group (p < 0.001). Significantly more patients in the primary clinic than the revision clinic had diabetes, hypertension and dyslipidemia, whereas more patients in the revision clinic than the primary clinic had reflux. Figure 1 compares the proportion of primary procedures of revision clinic patients and primary clinic patients. A larger proportion of patients in the revision clinic than in the primary clinic underwent laparoscopic adjustable gastric band (LAGB) procedures. Only 4% of patients in the revision clinic were referred from the primary clinic; they were referred if they had been previously discharged from the primary clinic. Many revision patients had their original surgeries performed in Alberta but outside of the primary clinic (52%), and 43% of patients were bariatric medical tourists — individuals who travel outside of the province in search of private medical care.

The majority of patients in the revision clinic were referred owing to weight regain (64%). This was true for all previous surgeries except biliopancreatic diversion with duodenal switch (BPD/DS); 75% of those who underwent BPD/DS were referred for malnutrition. Dysphagia was the second most common reason for referral to the revision clinic, regardless of primary surgery type (26%). In total, 21% of patients who underwent primary LAGB were referred for band complications, and 9% of all patients were referred solely for nutritional management. The final concern leading to referral was complications from the primary surgery, such as bowel obstruction. Many patients were referred for several simultaneous concerns (e.g., dysphagia and weight regain). In total, 7% of patients had already undergone some form of previous revision of the primary procedure before entering the revision clinic, and 12% of patients had undergone multiple bariatric procedures before presenting to clinic. In cases where patients presented years after their original procedures, records of what surgery was performed were often unavailable.

Owing to the rigorous screening process, only 22% (117 of 534) of patients ultimately received a revision procedure.

**Table 1. Demographic and clinical characteristics of the study sample**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Primary (n = 2769)</th>
<th>Revision (n = 534)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>44.0 ± 9.1</td>
<td>48 ± 10</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Female sex</td>
<td>83</td>
<td>90</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Initial BMI</td>
<td>49.9 ± 8.6</td>
<td>42.7 ± 10.8</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Comorbidity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>30</td>
<td>19</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>41.3</td>
<td>27.4</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>26.9</td>
<td>13</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Reflux</td>
<td>24</td>
<td>42.1</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

BMI = body mass index; SD = standard deviation.

![Fig. 1. Frequency of bariatric procedures in patients presenting to the revision clinic (top) and the primary bariatric clinic (bottom). BPD/DS = biliopancreatic diversion with duodenal switch; LAGB = laparoscopic adjustable gastric band; LRYGB = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; ORYGB = open Roux-en-Y gastric bypass; VBG = vertical banded gastroplasty.](image-url)
surgery. Predictably, this rate differed significantly from that of the primary clinic (32%, \( p < 0.001 \)). There were a total of 134 operations performed in 117 revision clinic patients (51 band removals and 83 bariatric revision procedures; Table 2). The most common revision surgery performed was ORYGB. This procedure was chosen because of its long safety and efficacy record as well as the relative ease of converting a vertical banded gastroplasty (VBG) pouch to an RYGB pouch. Patients were also offered sleeve gastrectomy (SG) if it was felt to be anatomically compatible with their previous operation(s). Patients who were not medically fit for RYGB or who did not want a major surgery but still had considerable symptoms from bands were offered band removal. Of the patients undergoing revision surgery, 4.9% had a combination of procedures (e.g., ORYGB and hernia repair). Of the patients who underwent LAGB, 36% \( (n = 48) \) required a band removal, and 35% \( (n = 17) \) of them went on to have a second definitive procedure. A few patients had anatomy compatible with laparoscopic RYGB (LRYGB; \( n = 4 \)) or SG (LSG; \( n = 13 \)), but most needed an open procedure because of scar tissue from multiple previous open operations.

The average duration of surgery in the revision clinic was \( 0.6 \pm 0.2 \) hours (range 0.4–1.0 hours) for band removal and \( 2.8 \pm 0.7 \) hours (range 1.4–5.1 hours) for revision surgery. The average duration of primary surgery was \( 1.3 \pm 0.5 \) hours for LSG, \( 2.4 \pm 0.8 \) hours for LRYGB and \( 0.6 \pm 0.4 \) hours for LAGB. The duration of revision ORYGB was 0.4 hours longer than the duration of primary LRYGB \( (p = 0.001) \). Median length of stay in hospital for primary procedures was 2 days (range 0–9 days) compared with 4 days (range 0–84 days) for revision procedures \( (p < 0.001) \).

Revision clinic patients experienced a significant decrease in BMI (from 44.7 ± 9.5 to 33.8 ± 7.5, percent)}
excess weight loss [%EWL] 61.2%, p < 0.001); their BMI at 12-month follow-up was similar to that of primary clinic patients (34.5 ± 7.0, %EWL 56.0%, p = 0.7; Fig. 2). Patients who were not considered appropriate for surgery and elected to be managed medically on average had a decrease in BMI from 42.5 ± 10.9 to 40.9 ± 10.7 (%EWL 14.3%, p = 0.007) within a median clinic follow-up time of 6 months (range 1–25 months). Follow-up at 1 year was 68% in the revision clinic compared with 74% in the primary clinic. Revision surgery had a higher complication rate than primary surgery; 41% of revision clinic patients experienced a complication compared with 15% of primary clinic patients (p < 0.001). Most of the revision surgery complications were wound infections (24%), and 56% of all complications resolved within 3 months. Table 3 lists the complications from the ORYGB. One patient who underwent LSG had a stricture, and 1 patient who underwent LRYGB had a bleed. Reoperation rates were significantly different between the revision and primary groups (10.8% v. 5.4%, p = 0.033). There were no deaths in either group.

**Discussion**

There is growing evidence to support treating obesity as a chronic disease. An emerging area of concern is patients with weight recidivism and complications after bariatric surgery seeking further surgical treatment. The Adult Bariatric Surgery Revision Clinic was created to manage the large number of such patients contacting the primary Edmonton Adult Bariatric Specialty Clinic, which already had a wait time of approximately 1 year for initial assessment. The revision program began with a single surgeon, and a second recently joined the program to manage the increasing volume of patients. To our knowledge the revision clinic is the first of its kind to solely manage revision patients and includes a multidisciplinary team based on our primary clinic. This clinic not only offers surgery, but also dietary advice, surgical follow-up for medical tourists and LAGB adjustments. Because some surgeons may decide not to manage these complex patients, without the revision clinic many patients are left without surgical or specialized lifestyle follow-up.

The revision clinic patients had significantly less diabetes, hypertension and dyslipidemia, but more reflux than primary clinic patients. The increased reflux is likely a result of anatomic changes from the previous surgery. Reflux is a common symptom even with an intact VBG, despite studies showing that the operation (when properly performed) is designed to decrease reflux.9,10 Patients who underwent LSG had the highest rates of reflux, with 57% of patients prescribed an antireflux therapy. There are few studies in the literature describing the presence or resolution of comorbidities in revision patients. However, 1 study11 showed similar levels of diabetes, hypertension and sleep apnea in primary and revision populations, whereas 2 others12,13 reported a marked increase in comorbidities, with weight regain after bariatric surgery and up to 22% of patients requiring further surgery. Several studies have reported pre- and postoperative BMI results similar to ours.14–16

Half of all revision patients had a prior VBG. Because of resultant complications and poor weight loss (21%–50%), this procedure was phased out as a primary bariatric procedure many years ago.17,18 “Three years after VBG, 56% of patients need revisional surgery.”19 Studies also suggest a 26%–48% rate of staple line failure within 5 years.20,21 Therefore, it is not surprising that a large portion of the revision clinic patients comprises those who underwent VBG. Ten-year follow-up of this procedure is uncommon, but 1 study reported only 26% of patients maintained weight loss in the long term.22

**Table 3. Complications of patients in the primary and revision bariatric clinic**

<table>
<thead>
<tr>
<th>Complication</th>
<th>Primary LSG (n = 366)</th>
<th>Primary LRYGB (n = 397)</th>
<th>Revision ORYGB (n = 66)</th>
<th>p value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leak</td>
<td>0</td>
<td>0.9</td>
<td>4.5</td>
<td>0.09</td>
</tr>
<tr>
<td>Bleed</td>
<td>1.7</td>
<td>6.0</td>
<td>0</td>
<td>0.03</td>
</tr>
<tr>
<td>SS/abscess</td>
<td>1.3</td>
<td>15.3</td>
<td>36.4</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Stricture</td>
<td>0.4</td>
<td>7.4</td>
<td>4.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Ulcer</td>
<td>1.3</td>
<td>8.7</td>
<td>9.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Fistula</td>
<td>0</td>
<td>0.4</td>
<td>9.1</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Bowel obstruction</td>
<td>0</td>
<td>0.7</td>
<td>4.5</td>
<td>0.03</td>
</tr>
<tr>
<td>Hernia</td>
<td>0.9</td>
<td>3.7</td>
<td>12.1</td>
<td>0.02</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>1.2</td>
<td>6.1</td>
<td>0.06</td>
</tr>
</tbody>
</table>

LRYGB = laparoscopic Roux-en-Y gastric bypass; LSG = laparoscopic sleeve gastrectomy; ORYGB = open Roux-en-Y gastric bypass; SS = surgical site infection.

*Patients who received laparoscopic adjustable gastric bands (n = 122) had none of the perioperative complications listed above.

†Comparing primary and revision Roux-en-Y gastric bypass.
In total, 25% of the revision clinic patients underwent LAGB. This is a popular procedure among medical tourists (86% had an LAGB), and often patients are not educated about the major dietary and lifestyle changes required after this surgery. Of the patients who presented to the revision clinic with band erosion/slippage or insufficient weight loss, 78% and 88%, respectively, were medical tourists, leading us to believe that poor follow-up may play a role in these postoperative issues.

With stringent criteria, only 22% of revision patients underwent surgical management, compared with 32% of patients in the primary clinic. Both of these percentages are lower than the operative volume in a private system owing to our process for patient selection and the need to allocate limited resources to candidates most likely to be successful. In our experience, patients with uncontrolled psychosocial and medical issues are more likely to have weight recidivism despite anatomically successful surgery, which is why our red flag system was developed. A multidisciplinary team is included in the bariatric clinics to optimize and approve appropriate patients for surgery, as per the American Society for Metabolic and Bariatric Surgery (ASMBS) 2004 consensus guidelines. In our experience, RYGB is the procedure of choice for revising previous bariatric surgery, specifically VBG, because of its effective weight loss results and safety. Not surprisingly, patients who underwent VBG most often qualified for further surgery (23% underwent RYGB), whereas most patients who had anatomically successful operations, such as prior SG or RYGB, were unlikely to need further surgical management (92%). In these patients, we often repaired hernias and performed panniculectomies. The first step for patients who underwent primary LAGB is to remove the gastric band. In the literature, only 16% of patients were reported to undergo a secondary procedure after LAGB removal, whereas 38% of such patients underwent a secondary procedure in our study.

Revisional bariatric surgery duration was on average 0.4 hours longer than primary bariatric surgery, and revision clinic patients remained in hospital a median of 2 days longer. These were statistically significant increases in resource use; however, an economic study would need to be performed to determine whether these resources outweigh the benefits of BMI reduction and improved lifestyle management in these patients.

After 1 year of follow-up, patients in both the revision and primary clinics had similar BMI (33). Revisional bariatric surgery was successful in substantially reducing BMI — significantly more than in the group managed only with lifestyle modification.

Due to adhesions, a high percentage of revision operations needed to be performed using an open technique. Wound infections were by far the most common complication, as expected with a large open incision in morbidly obese patients. Currently a combination of delayed primary closure and vacuum-assisted wound closure are being used to try and mitigate this complication. In future, to address certain complications, such as wound infections, more revision surgeries will be first attempted laparoscopically, as all primary surgeries are now done using minimally invasive techniques. Currently, the majority of our patients had primary open surgery and often had further open revisional surgery before arriving at our clinic. This demonstrates the need for an advanced skill set for bariatric surgeons who will be asked to manage this complex group of patients. Incisional hernias were also more common in the revisional group, most likely due to the large incision; the complications of 56% of these patients resolved within 3 months.

There was a higher attrition rate in the revision clinic than the primary clinic. Possible reasons include more resources in the primary clinic devoted to encouraging follow-up, medical tourism and the larger geographical area served by the revision clinic. For bariatric revision patients alone, the rate of follow-up was still lower than the primary clinic (68% vs. 74%) at 1 year. However, many of these patients were purposefully discharged after successful panniculectomies and hernia repairs.

Limitations

The limitations of this study include a large number of patients lost to follow-up in both the primary and revision clinics. However, most of these patients were not in the group treated with surgery. Furthermore, any retrospective review has limitations based on the quality of the data collection and unknown biases.

Conclusion

A bariatric revision clinic manages a wide variety of complex patients distinct from those seen in a primary clinic. Fewer revision clinic patients underwent surgery than primary clinic patients (22% vs. 32%); operative candidates are chosen based on favourable medical, anatomic and psychosocial factors, keeping in mind the resource constraints of a public health care system. The initial results from this bariatric revision clinic are encouraging. The weight loss and outcomes are comparable to those of a primary bariatric clinic with a higher complication rate and slightly increased resource use.

Contributors: C. Sheppard, D. Birch, S. Karmali and C. de Gara designed the study. C. Fulton and C. Sheppard acquired and analyzed the data, which S. Karmali also analyzed. C. Fulton, C. Sheppard and D. Birch wrote the article, which all authors reviewed and approved for publication.
References


Nous croyons au libre accès à la recherche

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Thirteen-year wear rate comparison of highly crosslinked and conventional polyethylene in total hip arthroplasty: long-term follow-up of a prospective randomized controlled trial

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Background: The purpose of this study was to report the radiographic wear rates from a previous randomized controlled trial of first-generation highly crosslinked versus conventional polyethylene in total hip arthroplasty (THA) at a minimum of 13 years’ follow-up.

Methods: Patients returned for radiographic imaging and radiostereometric analysis (RSA). Radiographs were reviewed for the presence of osteolysis or component loosening. Femoral head penetration (which includes both wear and creep) was measured using RSA. We compared Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), 12-Item Short Form Health Survey (SF-12) and Harris Hip Scores (HHS) with preoperative values.

Results: There was 1 revision in each group. There was no difference in WOMAC, SF-12, or HHS outcome scores between the highly crosslinked and conventional polyethylene groups (all \(p \geq 0.13\)). Wear rate was lower with crosslinked polyethylene than conventional polyethylene (0.04 ± 0.02 mm/year v. 0.08 ± 0.03 mm/year, \(p = 0.007\)).

Conclusion: First-generation crosslinked polyethylene demonstrates greater wear resistance than conventional polyethylene after 13 years of implantation. Crosslinked polyethylene continues to outperform conventional polyethylene into the second decade of implantation.

Contexte: Le but de cette étude était de faire rapport sur les taux d’usure à la radiographie dans la foulée d’un essai randomisé et contrôlé antérieur sur un polyéthylène hautement réticulé de première génération c. classique pour la prothèse totale de la hanche (PTH) après un minimum de 13 ans de suivi.

Méthodes: Les patients se sont de nouveau présentés pour subir des radiographies et une analyse radiostéréométrique (ARS). On a vérifié à la radiographie la présence d’ostéolyse ou de desséclement. La pénétration de la tête fémorale (qui inclut l’usure et le flasque) a été mesurée par ARS. Nous avons comparé l’indice WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index), le questionnaire SF-12 (questionnaire sur la qualité de vie en lien avec la santé en 12 points) et le score HHS (score de Harris pour la hanche) aux valeurs préopératoires.

Résultats: Il y a eu 1 révision dans chaque groupe. On n’a noté aucune différence pour ce qui est des scores WOMAC, SF-12 ou HHS entre les groupes ayant reçu la prothèse de polyéthylène hautement réticulée c. classique (tous \(p \geq 0.13\)). Le taux d’usure a été moindre avec le polyéthylène réticulé qu’avec le polyéthylène classique (0,04 ± 0,02 mm/an c. 0,08 ± 0,03 mm/an, \(p = 0,007\)).

Conclusion: Le polyéthylène réticulé de première génération résiste mieux à l’usure que le polyéthylène classique 13 ans après l’implantation. Le polyéthylène réticulé continue de surclasser le polyéthylène classique au-delà des 10 premières années suivant l’implantation.

Highly crosslinked polyethylene was introduced for total hip arthroplasty (THA) with the goal of increasing wear resistance and improving implant longevity.1 Between November 1999 and October 2001, 100 consecutive patients from our institution were enrolled in a prospective randomized controlled trial.2 Patients were divided into 2 groups (of 50 patients each) and received either a conventional polyethylene liner
(Trilogy, Zimmer Inc.) or a first-generation highly crosslinked polyethylene liner (Longevity, Zimmer Inc.). Patients and research staff were blinded to the intervention. The liners all had a 10° lip and an outer diameter of 48–58 mm. Both groups received a cemented collared femoral stem with a 28 mm diameter cobalt-chrome femoral head (VerSys, Zimmer Inc.) and a cementless tri-spiked acetabular cup (Trilogy, Zimmer Inc.). The operations were performed through a modified lateral approach by 1 of 5 experienced high-volume (>100 cases per year) arthroplasty surgeons.

Results for this cohort were previously reported after a mean follow-up of 6.8 years. Age at surgery (mean 72 years) and body mass index (BMI; mean 29.7) was identical between groups. The male:female ratio was 14:36 in the conventional polyethylene group and 17:33 in the highly crosslinked polyethylene group. At the time of the previous report, 1 patient was lost to follow-up in each of the groups, and there were 2 deaths in the conventional group and 7 in the highly crosslinked group. There were no differences between the 2 polyethylene groups for the Harris Hip Score (HHS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), or 12-Item Short Form Health Survey (SF-12). The mean steady state femoral head penetration rate for the first 5 years postimplantation (excluding bedding-in) was lower in the highly crosslinked group than the conventional group (0.003 ± 0.022 mm/year vs. 0.051 ± 0.027 mm/year, p = 0.006).

Although there have been a number of reports evaluating the wear resistance of highly crosslinked polyethylene at short- to mid-term follow-up, there have been few reports exceeding 10 years’ implantation time and even fewer that were part of a prospective, randomized controlled trial. The purpose of the present study was to evaluate wear for first-generation highly crosslinked polyethylene at a minimum of 13 years’ implantation, updating our previous report at a longer term follow-up.

METHODS

Patients who had been enrolled in the prospective randomized controlled trial were eligible for inclusion. We reviewed charts to identify cases of revision or death. We attempted to contact all other patients to determine the status of their hip and, where possible, schedule them for a follow-up visit, including radiographic evaluation.

Patient recruitment for the long-term follow-up was extremely challenging owing to the age of the patients. After recruiting 16 patients — 8 in each polyethylene group — we performed a post hoc power calculation based on the measured total head penetration. We determined that we had sufficient power (81.6%) to measure a significant difference with an α of 0.05 and elected to stop recruiting patients to the clinic for wear measurement. Our institutional review board approved the study, and all participants provided informed consent.

At the time of the latest follow-up, patients completed the clinical outcome scores from the original study: the HHS, WOMAC and SF-12. Each patient also underwent conventional radiographic imaging. We reviewed the anteroposterior and lateral view images for signs of osteolysis. The presence of lesions (if any) was noted.

Femoral head penetration due to wear was measured by radiostereometric analysis (RSA), using the validated centre index method. Patients underwent a standard supine RSA examination with simultaneous, bilateral calibrated radiograph exposures. The 3-dimensional difference between the current location of the femoral head and the original location of the femoral head (at the time of the index procedure, before any wear occurred) was calculated as the total femoral head penetration. We calculated the femoral head penetration rate on a per-patient basis by dividing the total femoral head penetration by the implantation time.

Statistical analysis

We used t tests to compare demographic data, clinical outcome scores and wear measurements between the groups. We considered results to be significant at p < 0.05 for all statistical tests.

Funding

No external source of funding was received for this follow-up study. Financial support for the original study was provided by Zimmer Inc., to support the salaries of a research nurse (who enrolled patients and gathered outcome data) and a research technician (who performed the radiographic wear analysis).

RESULTS

After a minimum of 13 years, 29 patients from the original study had died, and 14 patients were lost to follow-up. This left 57 patients eligible for follow-up, and of these 2 patients were revised and 55 patients were alive without revision (Fig. 1). One revision occurred in each of the conventional and highly crosslinked polyethylene groups. In both revision cases, the reason for revision was loosening of the femoral stem. The revised patient in the conventional polyethylene group was a woman whose implant was revised at 5.5 years, and the patient in the highly crosslinked group was a man whose implant was revised at 6.5 years. Among the 16 patients who returned to clinic for RSA wear measurement after 13 years, we observed no differences in any demographic characteristics between the conventional and highly crosslinked polyethylene groups. There were 2 men and 6 women in the conventional polyethylene group, and 1 man and 7 women in the highly crosslinked polyethylene group. The mean duration since implantation was 13.6 years (range 13–15 years,
$p = 0.89$ between groups). The mean age at the time of the procedure was 67.5 years (range 56–77 years, $p = 0.85$ between groups), which was younger than that of the full original cohort of 100 patients (mean 72 years). The mean BMI was 28.4 (range 23–35, $p = 0.24$ between groups).

Femoral head penetration was on average 58% greater in the conventional polyethylene group ($p = 0.013$). The total femoral head penetration (Fig. 2) in the conventional polyethylene group was 1.046 mm (range 0.549–1.428 mm) and 0.622 mm (range 0.361–1.037 mm) in the highly crosslinked polyethylene group. Converted to a yearly penetration rate (which included the bedding-in period), the rate was again twice as high in the conventional polyethylene group ($p = 0.007$). The penetration rate (Fig. 3) was 0.077 mm/year (range 0.040–0.106 mm/year) in the conventional polyethylene group and 0.042 mm/year (range 0.027–0.079 mm/year) in the highly crosslinked polyethylene group.

The presence of osteolysis was noted in only 1 patient, who was in the conventional polyethylene group. The patient was a man aged 55.6 years at the time of the procedure, with a BMI of 24.9. His RSA examination at 13.7 years revealed a total femoral head penetration of 1.4 mm, for a wear rate of 0.104 mm/year. The osteolytic lesion was noted surrounding the acetabular cup.

There was no difference in the HHS, WOMAC, or SF-12 clinical outcome scores between the highly crosslinked and conventional polyethylene patients who returned for RSA wear analysis (Table 1). There was also no difference in the clinical outcomes scores between the highly crosslinked and conventional polyethylene patients who had returned to clinic between 7 and 13 years after the index procedure but who were not available for the RSA wear analysis (Table 2).

**DISCUSSION**

A large number of patients were deceased or lost to follow-up at 13 years. This is a result of the original inclusion criteria for the trial, which preferentially selected older patients owing to concerns surrounding the longevity of the then new crosslinked polyethylene material. The patients who did return at 13 years were all among the youngest patients enrolled in the original study, with a
mean age of 65 years at the time of the procedure versus 72 years for the overall group. Other patients who were not lost to follow-up or deceased, but who did not return for the 13-year follow-up, tended to be the oldest patients and were unable or unwilling to come back to the clinic.

There was no difference in clinical outcomes or survival between the conventional and highly crosslinked polyethylene groups. This may be in part because of the selection of older patients at the time of the index procedure, as these patients are likely to be less demanding of their implant. The average wear rate in the conventional group was well below the osteolysis threshold. The majority of studies reporting on survival at 5 or more years have found no difference between conventional and highly crosslinked polyethylene, as was the case in the present study. Other studies have found a greater revision rate in the conventional polyethylene group. The most recent report of the Australian Orthopaedic Association National Joint Replacement Registry (2014) has 13-year data, reporting a 9.0% revision rate for metal on conventional polyethylene and a 4.6% revision rate for metal on highly crosslinked polyethylene. Therefore the results of the present study may be applicable only to this implant and to the elderly patient population studied.

Most notably, polyethylene wear was significantly different between the 2 groups. The conventional group demonstrated twice the total femoral head penetration and femoral head penetration rate of the highly crosslinked group.

Table 1. Clinical outcome scores for patients with a latest follow-up of at least 13 years

<table>
<thead>
<tr>
<th>Score</th>
<th>Crosslinked, n = 8</th>
<th>Conventional, n = 8</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WOMAC Latest</td>
<td>69.2 (44.2–100.0)</td>
<td>67.9 (28.3–94.2)</td>
<td>0.92</td>
</tr>
<tr>
<td>Preoperative</td>
<td>39.5 (22.8–69.9)</td>
<td>33.3 (21.8–49.9)</td>
<td>0.36</td>
</tr>
<tr>
<td>Harris Hip Score Latest</td>
<td>85.6 (60.0–95.0)</td>
<td>89.5 (82.0–100.0)</td>
<td>0.51</td>
</tr>
<tr>
<td>Preoperative</td>
<td>37.3 (22.0–58.0)</td>
<td>37.5 (28.0–49.0)</td>
<td>0.96</td>
</tr>
<tr>
<td>SF-12 mental score Latest</td>
<td>57.5 (44.3–64.7)</td>
<td>54.2 (45.6–69.2)</td>
<td>0.45</td>
</tr>
<tr>
<td>Preoperative</td>
<td>53.9 (43.1–60.6)</td>
<td>45.4 (33.7–65.9)</td>
<td>0.13</td>
</tr>
<tr>
<td>SF-12 physical score Latest</td>
<td>33.9 (22.3–51.4)</td>
<td>33.9 (25.3–49.8)</td>
<td>0.99</td>
</tr>
<tr>
<td>Preoperative</td>
<td>29.8 (22.8–50.0)</td>
<td>26.3 (19.7–36.7)</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Table 2. Clinical outcome scores for patients with a latest follow-up of at least 7 years (therefore exceeding the previous follow-up report)

<table>
<thead>
<tr>
<th>Score</th>
<th>Crosslinked, n = 8</th>
<th>Conventional, n = 8</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WOMAC Latest</td>
<td>71.89 ± 21.14 (22)</td>
<td>70.01 ± 22.15 (18)</td>
<td>0.79</td>
</tr>
<tr>
<td>Preoperative</td>
<td>39.74 ± 15.30 (48)</td>
<td>40.74 ± 15.38 (48)</td>
<td>0.75</td>
</tr>
<tr>
<td>Harris Hip Score Latest</td>
<td>86.25 ± 12.35 (20)</td>
<td>88.25 ± 10.73 (16)</td>
<td>0.61</td>
</tr>
<tr>
<td>Preoperative</td>
<td>35.84 ± 12.26 (49)</td>
<td>39.51 ± 11.60 (50)</td>
<td>0.13</td>
</tr>
<tr>
<td>SF-12 mental score Latest</td>
<td>53.96 ± 8.65 (22)</td>
<td>51.27 ± 9.50 (19)</td>
<td>0.35</td>
</tr>
<tr>
<td>Preoperative</td>
<td>52.97 ± 10.66 (48)</td>
<td>54.16 ± 12.65 (48)</td>
<td>0.62</td>
</tr>
<tr>
<td>SF-12 physical score Latest</td>
<td>37.41 ± 11.86 (22)</td>
<td>35.46 ± 11.49 (19)</td>
<td>0.60</td>
</tr>
<tr>
<td>Preoperative</td>
<td>27.14 ± 8.45 (48)</td>
<td>25.86 ± 6.03 (48)</td>
<td>0.40</td>
</tr>
</tbody>
</table>

SD = standard deviation; SF-12 = 12-Item Short Form Health Survey; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.
The better performance by highly crosslinked polyethylene is consistent with virtually all other studies of wear in hip arthroplasty at mid to long-term follow-up. The femoral head penetration rate for highly crosslinked polyethylene in this study (mean of 0.042 mm/year, including the bedding-in period) falls within the middle of the range of previously reported wear rates and is in fact exactly the same as the average found in a systematic review of 28 studies of first-generation highly crosslinked polyethylene.11,9 The average rates for both highly crosslinked and conventional polyethylene in this study fell below the commonly accepted osteolysis threshold of 0.100 mm/year. Only 1 patient showed any signs of osteolysis: a patient with a conventional polyethylene implant and a mean wear rate just above the osteolysis threshold at 0.104 mm/year.

Limitations

The primary limitation of this study is that only 16 patients returned to clinic for complete RSA wear analysis at 13 years; however, this number provided adequate statistical power to detect a significant difference. As described earlier, the number of patients still living and available for follow-up was related to the original study design, in which older patients were preferentially included in the trial. The difficulty of bringing back patients for long-term follow-up is well understood. Acknowledging the limitations with respect to radiographic follow-up, we were able to account for 86 of the 100 enrolled patients, with 14 patients lost to follow-up. This is one of the very few prospective randomized trials reporting long-term follow-up on highly crosslinked polyethylene.

Conclusion

Like most institutions, ours has entirely switched to the use of highly crosslinked polyethylene for total hip arthroplasty. This first-generation highly crosslinked polyethylene appears to continue to do well at 13 years, with half of the femoral head penetration rate as conventional polyethylene. Though survival is currently equivalent between the 2 groups in this study (with 1 revision per group), this has not been the case when comparing the long-term results between other cohorts of conventional and highly crosslinked polyethylene groups at more than 10 years’ follow-up treated at our institution.13 The hope would be that the decreased wear rate in this highly crosslinked group could potentially translate to increased longevity in the second and third decade after surgery.

Affiliations: From the Division of Orthopaedic Surgery, London Health Sciences Centre, London, Ont. (Teeter, Somerville, MacDonald, McCalden, Naudie); the Surgical Innovation Program, Lawson Health Research Institute, London, Ont. (Teeter); and the Imaging Research Laboratories, Robarts Research Institute, London, Ont. (Yuan).

Competing interests: S. MacDonald reports royalties, consultant fees and research support from DePuy, A Johnson & Johnson Company; stock options from Hip Innovations Technology and JointVue; and research support from Smith & Nephew and Stryker. R. McCalden reports consultant and speaker fees from Smith & Nephew and research support from Smith & Nephew, Johnson & Johnson, Depuy and Stryker. D. Naudie reports financial or material support from Depuy, A Johnson & Johnson Company; royalties, financial or material support, speaker fees, and consultant fees from Smith & Nephew; and financial or material support, consultant fees and speaker fees from Stryker. No other competing interests declared.

Contributors: M. Teeter, S. MacDonald, R. McCalden and D. Naudie designed the study. M. Teeter, X. Yuan and L. Somerville acquired and analyzed the data. M. Teeter wrote the article, which all authors reviewed and approved for publication.

References

IN MEMORIAM OF DR. TOM STARZL

The world lost one of its pioneers in transplantation when Tom Starzl died. It was Dr. Starzl’s conviction and tenacity, coupled with his scientific and experimental rigor, surgical skills and extraordinary commitment of time and person that brought us into the present “transplant era” in which transplantation of the liver, kidney, pancreas, lung and heart is now ubiquitous. While his numerous achievements have had world-wide impact on our understanding and the clinical practice of transplantation, his legacy will live on through the hundreds of surgeons and physicians who he trained and has influenced throughout his illustrious career.

My personal experience with Dr. Starzl was brief. I returned to a staff position in Toronto in 1984, having been trained in liver surgery by Drs. Bernie Langer and Bryce Taylor, expecting a career doing portosystemic shunts. Our recently graduated fellow, Leonard Makowka went to Pittsburgh in 1985 to train under Dr. Starzl in the new and rapidly evolving area of liver transplantation. Recognizing the major advances that Starzl (and Roy Calne in England) had achieved in liver transplantation from 1982 to 1984, Bernie started our liver transplant program in Toronto in the fall of 1985. To complement the work that we were doing in the lab, I went to Pittsburgh for a week in May, 1986. At that time Pittsburgh was the dominant liver transplant program in North America (and the world!), doing more than 250 livers per year, and during my 5-day visit, I saw 4 liver transplants. On my last day there, I was privileged to scrub with Dr. Starzl as his third assistant on a patient with Budd Chiari syndrome. It was an extraordinary experience, and like hundreds of his other former fellows and visitors to Pittsburgh, I too remain heavily influenced by him.

Dr. Starzl’s legacy will be perpetuated not just by the many patients whose lives he saved and improved through transplantation, but also through the hundreds of physicians and surgeons he mentored and has influenced and their transplant patients.

Paul D. Greig, MD
Affiliation: Division of General Surgery, University of Toronto, Toronto, Ont.

Reference
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SURGICAL MENTORSHIP IN CANADA IN 2017

I am writing in response to the editorial in the April issue of CJS detailing the history and relevance of surgical mentorship in Canada. As a participant in a mentorship program, I can personally attest to the relevance of this in the current surgical environment. Mentorship does not have to be exclusively for newly trained surgeons, but should also form part of the armamentarium for most surgical departments and can benefit surgeons in all aspects of their clinical practice. The ability to learn new techniques as well as brush up on existing techniques can only serve to reinforce the standard of care as espoused by the Royal College of Physicians and Surgeons of Canada. As a rural surgeon in Northern Saskatchewan, the ability to learn new procedures is often hampered by lack of time and having to travel great distances.

As a result of my mentorship program, I was able to learn advanced laparoscopic skills in the very hospital in which I conduct my clinical practice, under the auspices of the chief of surgery, who had been performing the procedure for more than 20 years. A surgical audit of my technique is currently underway, and preliminary results attest to the efficacy of surgical mentorship. Another often overlooked aspect of mentorship is working with nurses and operating room staff experienced in the technique, which only serves to reinforce the technique in the absence of the surgical mentor.

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Reference
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Q. WHAT IS HS?
A. Hidradenitis Suppurativa (HS) is a chronic, painful, inflammatory skin disease which affects 1-4% of the general adult population. It is characterized by boils usually occurring where certain sweat glands are located, such as under the breasts, buttocks and inner thighs. The boils can develop and connect, forming draining sinuses which discharge foul-smelling pus.

Q. WHAT CAUSES HS?
A. The cause of HS is unclear. It is thought that certain genetic markers and defects within hair follicles are at the root of the disease. Risk factors include smoking and obesity. About one-third of patients report a family history of HS. HS has been reported to co-occur with several comorbid conditions—mostly, inflammatory bowel disease.

Q. HOW DOES HS IMPACT QUALITY OF LIFE?
A. HS is often undiagnosed or misdiagnosed. It interferes with social interactions, job performance and intimate relationships—often leading to isolation. It is painful and causes embarrassment.

Q. DO PEOPLE SUFFERING FROM HS GO TO THE ER FOR TREATMENT?
A. People with HS come to the emergency room in severe pain and discomfort requiring assistance with the draining of the boils during a flare-up. It’s not unusual for patients to go home undiagnosed.

Q. IS THERE A CURE FOR HS?
A. There is currently no cure for HS. Early diagnosis and proper management is important for a patient’s quality of life. The first step for those with HS is to speak to their dermatologist to get an accurate diagnosis.

Q. HOW CAN HS BE TREATED?
A. Medical treatments for HS have included antibacterial washes, topical clindamycin, various systemic antibiotics, hormonal therapies, systemic retinoids, laser treatment, intralesional steroid injections and biologics. Surgical de-roofing or wide excision procedures have long been the definitive treatment for severe HS. There is no guarantee that HS will not recur in the previously excised areas.