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The benefits and risks of requiring researchers to share data

For many young authors, the steps to publication are frustrating and annoying. Their older peers can gleefully tell them that it was worse in the old days. Not too long ago, manuscripts were prepared by typewriter. If a reviewer requested changes, great ingenuity was required to avoid disrupting the citation sequence too much. If a paper was refused, submission to another journal usually required complete retyping of the manuscript to meet its different specifications. In 1978, a group of journal editors met in Vancouver, BC, to address this latter problem by developing uniform requirements for manuscripts submitted to biomedical journals. Not only did they give us the Vancouver citation style, they also continued as the International Committee of Medical Journal Editors (ICMJE) to promote quality in reporting of medical science. The Canadian Journal of Surgery chose then, and continues now, to follow ICMJE recommendations.

The scope of ICMJE broadened from requirements for manuscript preparation to include “conduit, reporting, editing and publication of scholarly work in medical journals.” While CJS highlighted issues, such as the minimum contribution for authorship and fraudulent reporting, ICMJE also tried to improve the definition of the roles and responsibilities of reviewers, editors, publishers and owners with respect to bias, conflict of interest and editorial freedom. In 1997, a clinical trial registry, now known as ClinicalTrials.gov, was established in the United States to give the public access to research data, particularly about pharmaceutical therapies. ICMJE exploited the existence of this registry to require preregistration of clinical trials submitted for publication to supporting journals in order to avoid the suppression of trials with negative outcomes. CJS adopted this requirement.

Scientific reports traditionally present aggregate data. Presentation may require intense statistical manipulation, such as in certain types of survival curves, comparison between which may involve complex computer code. In January of this year, ICMJE posted a provisional policy to require reports to include a statement regarding the availability of underlying data for sharing. This statement should include information regarding the trial protocol (which may be available from ClinicalTrials.gov); the statistical code used and the data set. While the primary aim is to allow for the confirmation of research claims, other benefits will include better archiving of data, better meta-analysis and the possibility of secondary analysis.

The strongest objections to the proposal have come from members of the cardiovascular clinical trials community, who are concerned that compliant authors will be disadvantaged by sharing data with others who have neither paid nor worked for the results. They are probably expressing in polite terms what is much more acutely felt by commercial sponsors. They counter-propose a 24-month moratorium on data sharing to permit authors the opportunity for secondary analysis. There are, however, other risks to data sharing. Patient identification, imagined or real, may be possible using residual identifiers despite current de-identification techniques. Hostile reviewers can use the data to discredit researchers in a forum where rebuttal is difficult or impossible. Archiving data and answering queries have costs that may extend beyond the budget and period of the research. The co-operation of patients and research ethics boards has not been established. Finally, methods to protect researchers from frivolous requests have not been considered.

The current proposal applies only to data presented in aggregate form in reports of prospective trials of an intervention in humans, and it is permissible to state that data are not available. Extension of the policy is inevitable. The

**Summary**

The International Committee of Medical Journal Editors has sponsored many developments in medical research reporting that have improved the quality of research. Their proposal to require a statement by researchers regarding the availability of underlying data for sharing has the potential for a significant advance in medical knowledge. The Canadian Journal of Surgery supports the initiative and will develop mechanisms to support authors in meeting this new requirement.
logic for data sharing applies to all biomedical research. Funding agencies do not currently require data sharing, but most likely will in the future. Registration of a trial on ClinicalTrials.gov now requires the disclosure of data sharing arrangements.

CJS supports the goals of the data sharing proposal. We will make available to authors a consensus regarding adequate participant de-identification and safe storage of experimental data. We will develop a model confidentiality agreement that would allow bona-fide researchers access to data for the purpose of analyzing the published results, with a requirement that reports be submitted to the journal for publication so that the original author has an opportunity to reply. All other agreements for data sharing will be between the researcher and the applicant according to current practice. Data sharing, properly administered, represents a generational advance in the development of medical knowledge.

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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). None declared for V.C. McAlister.

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References

Les avantages et les risques d’exiger que les chercheurs partagent leurs données

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

RéSUMÉ

Le Comité international des rédacteurs de revues médicales a rendu possibles de nombreuses avancées dans la communication des résultats de recherche médicale qui ont amélioré la qualité de la recherche. Sa proposition de demander aux chercheurs une déclaration sur l’accessibilité de données sous-jacentes à partager pourrait faire grandement progresser les connaissances médicales. Le Journal canadien de chirurgie appuie l’initiative et élaborera des mécanismes visant à aider les auteurs à respecter cette nouvelle exigence.

Pour beaucoup de jeunes auteurs, le processus de publication est frustrant et irritant. Leurs pairs plus âgés leur diront volontiers que les choses étaient bien pires autrefois. Il n’y a pas si longtemps, les manuscrits étaient préparés à la machine à écrire. Si un examinateur demandait des changements, il fallait faire preuve d’une grande ingéniosité pour éviter de trop perturber la séquence des citations du texte. Si un article était refusé, il fallait généralement pour le soumettre à une autre revue le retaper en entier pour respecter les différentes exigences. En 1978, des rédacteurs en chef se sont réunis à Vancouver (C-B) pour régler ce dernier problème : ils ont mis en place des exigences uniformes pour les manuscrits soumis à des revues biomédicales. Ils nous ont non seulement donné le style de citation Vancouver, mais ils ont aussi formé le Comité international des rédacteurs de revues médicales (CIRRM), qui continuera à promouvoir la qualité des rapports de recherche médicale. Le Journal canadien de chirurgie (JCC) a alors choisi de suivre les recommandations du CIRRM — il le fait d’ailleurs toujours aujourd’hui.

La portée des activités du CIRRM s’est élargie pour inclure en plus des exigences de préparation des manuscrits la conduite, les rapports, l’édition et la publication des travaux universitaires dans les revues médicales1. Alors que le JCC mettait en évidence des problèmes, comme la contribution minimale pour l’attribution de la paternité d’une œuvre et les rapports frauduleux, le CIRRM tentait d’améliorer la définition des rôles et
responsabilités des examinateurs, des rédacteurs en chef, des éditeurs et des propriétaires en ce qui concerne la partialité, les conflits d’intérêts et la liberté éditoriale2,3. En 1997, un registre des essais cliniques, appelé aujourd’hui ClinicalTrials.gov, a été établi aux États-Unis pour donner au public accès aux données de recherche, plus particulièrement au sujet des traitements pharmaceutiques. Le CIRRM a tiré parti de l’existence de ce registre et demandé la préinscription des essais cliniques soumis pour publication aux revues qui l’appuient afin d’éviter la suppression des essais aux résultats négatifs, exigence que le JCC a adoptée.

Les rapports scientifiques présentent habituellement des données agrégées, ce qui peut nécessiter d’intenses manipulations statistiques, par exemple, dans certains types de courbes de survie, des comparaisons utilisant un code informatique complexe. En janvier dernier, le CIRRM a publié une politique provisoire demandant que les rapports contiennent une déclaration sur l’accessibilité de données d’appui à partager4. Cette déclaration devrait comprendre des renseignements sur le protocole d’essai (qui pourrait être accessible sur ClinicalTrials.gov), le code statistique utilisé et l’ensemble de données. Bien que le but principal soit de permettre la confirmation de la propriété des recherches, cette exigence entraînera d’autres avantages, comme l’amélioration de l’archivage des données et des méta-analyses, et la possibilité d’effectuer une analyse secondaire.

Les principales objections à la proposition viennent de membres de la communauté des essais cliniques cardiovaiscu, les qui craignent que les auteurs s’y conformant soient désavantagés de devoir partager leurs données avec des personnes qui n’ont rien payé et n’ont pas travaillé pour obtenir les résultats. Ils expriment probablement en termes polis ce que les commanditaires commerciaux ressentent beaucoup plus intensément. Ceux opposants proposent plutôt un moratoire de 24 mois sur le partage des données. Cette proposition doit comprendre une déclaration sur l’accessibilité des données qui participe à partager (qui pourrait être accessible sur ClinicalTrials.gov), le code statistique utilisé et l’ensemble des données. Bien que le but principal soit de permettre la confirmation de la propriété des recherches, cette exigence entraînera d’autres avantages, comme l’amélioration de l’archivage des données et des méta-analyses, et la possibilité d’effectuer une analyse secondaire.

La proposition actuelle ne s’applique qu’aux données présentées sous forme agrégée dans les rapports d’études prospectives portant sur une intervention chez l’homme, et il est permis de déclarer que les données ne sont pas accessibles. L’élargissement de la politique est inévitable. La logique derrière le partage des données s’applique à toute la recherche biomédicale. Les organismes de financement n’existent actuellement pas le partage des données, mais ils le feront probablement à l’avenir. D’ailleurs, l’inscription d’un essai sur ClinicalTrials.gov nécessite maintenant la divulgation des ententes de partage des données.

Le JCC appuie les objectifs de la proposition sur le partage des données. Nous mettrons à la disposition des auteurs un consensus sur l’anonymisation adéquate des participants et le stockage sécuritaire des données expérimentales. Nous créerons également un modèle d’entente de confidentialité qui permettra aux chercheurs sérieux d’accéder aux données dans le but d’analyser les résultats publiés, à la condition qu’ils présentent leurs rapports à la revue pour publication afin que l’auteur original ait l’occasion de répondre. Toutes les autres ententes de partage des données seront conclues entre le chercheur et le demandeur selon la pratique actuelle. Le partage des données, bien administré, représente une avancée générationnelle dans l’avancement des connaissances médicales.

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Références

Canada has lost a remarkable surgeon and leader. Dr. Frederick Griffith “Griff” Pearson, aged 90, died in Kitchener, Ont., on Aug. 10, 2016, surrounded by his wife, Hilppa Pearson, and his family.

Griff was born and raised in Toronto as the son of an optometrist and an enlightened mother. A bright student, he attended the University of Toronto, where his science teacher, Dr. Kroll, encouraged him to become a physician. In 1949, he graduated as the silver medalist in medicine at the University of Toronto. After his internship at the Toronto General Hospital (TGH), he spent a year in general practice in Port Colbourne, Ont. He then returned to the University of Toronto, where he did research under Wilfred G. Bigelow, studying hypothermia for cardiac surgery and the “mysteries of hibernation.” His love of the North drew him to the secluded town of Wawa, Ont., for 3 years where the lack of speciality care exposed him to all aspects of medicine, surgery and obstetrics. He thrived in this environment and developed his great sense of always putting the patient first. In 1955, he returned to complete his general surgery residency at the University of Toronto. In 1957, while a resident, he represented surgery in the establishment of a 4-bed respiratory failure unit at TGH, the first in Canada.

After becoming a fellow of the Royal College of Physicians and Surgeons of Canada in 1958, he was advised by Drs. Fred Kergin and Robert Janes to pursue further studies in pulmonary and esophageal surgery. He received a McLaughlin travelling fellowship that allowed him to work with Mr. Ronald Belsey at the Frenchay Hospital in Bristol, UK. Not only did Mr. Belsey teach Griff the nuances of esophageal surgery, he engrained in him the importance of careful lifelong follow-up of patients undergoing new operations. The information garnered from these clinics allowed Griff to improve on Mr. Belsey’s Mark IV hiatus hernia operation by adding the Collis gastroplasty to lengthen the esophagus in patients with a foreshortened esophagus. In 1960, Griff travelled to Copenhagen, Denmark, to learn about prolonged mechanical ventilation by positive pressure ventilation. He observed severe injuries to the larynx and trachea that led him to develop a lifelong interest in tracheal and laryngeal surgery. In Stockholm, Sweden, he visited Dr. Eric Carlens to investigate the use of a double-lumen (Carlens) tube to provide single-lung ventilation during thoracotomies. Dr. Carlens also showed Griff the use of a mediastinoscope to biopsy paratracheal, hilar and subcarinal lymph nodes in the staging of lung cancer. On his return to Toronto, Griff championed this technique throughout North America to prevent futile thoracotomies in patients with unresectable mediastinal lung cancer metastasis. With the help of Dr. Bob Ginsberg, he formed the first surgical group in Toronto to participate and lead a North American cooperative group (The Lung Cancer Study Group). Ever since, the Toronto team has been a leader...
in clinical trials of lung and esophageal cancer treatment in North America.

In 1960, Griff returned to TGH, where he quickly established himself as a thoughtful clinical surgeon and investigator. In 1967, he joined Dr. Norman Delarue in starting the first Division of Thoracic Surgery in Canada. Griff’s students called him “the Pied Piper of thoracic surgery.”

His cheerfulness, curiosity, sense of wonder, clear communication skills and surgical agility attracted surgeons, physicians and nurses from around the world to join the TGH thoracic team. Griff established a training program in thoracic surgery that was recognized by the Royal College of Physicians and Surgeons of Canada in 1977 as a separate specialty. This program has been a template for training programs throughout North America and the world. The majority of graduates of the “Toronto Program” are now leaders in the field of general thoracic surgery in Canada and throughout North and South America, Europe and Asia.

Griff established the first research laboratory in thoracic surgery in Canada. The Thoracic Surgical Research Laboratories have made seminal contributions in airway surgery, lung transplantation and lung oncology. Based on research discoveries in the lab, the TGH lung transplant team of Joel Cooper, Bill Nelems, Tom Todd, Mel Goldberg and Alex Patterson carried out the first successful lung transplant in the world in 1983. Under the leadership of Drs. Shaf Keshavjee and Tom Waddell, this group continues to innovate in lung transplantation and tissue regeneration and now carries out more than 120 lung transplants a year.

Always humble, Griff was honoured by being appointed as the surgeon-in-chief at TGH, the president of the American Association of Thoracic Surgeons, a member of the Order of Canada and a honorary fellow of 5 international thoracic societies. Griff was the lead editor of the first and second editions of the popular textbook Pearson’s Thoracic and Esophageal Surgery. Recently, he coauthored Evolution of Thoracic Surgery in Canada with Drs. Jean Deslauriers and Bill Nelems.

Griff’s greatest legacy was as a teacher and mentor. He had a clear understanding of the practice of thoracic surgery and all of its nuances. His ethics, teaching and discoveries continue to influence thoracic surgeons around the world. Canada has truly lost a surgical genius.

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Competing interests: None declared.
Unpacking the financial costs of “bariatric tourism” gone wrong: Who holds responsibility for costs to the Canadian health care system?

Recently in this journal, Kim and colleagues1 reported on the findings of a study of the financial costs to the health care system associated with patients travelling across international borders for bariatric procedures, which constitutes a form of medical tourism. Canadians are motivated to travel abroad for bariatric surgery owing to wait times for care and restrictions on access at home for various reasons. While such surgery abroad is typically paid for privately, if “bariatric tourists” experience complications or have other essential medical needs upon their return to Canada, these costs are borne by the publicly funded health system. Kim and colleagues1 conservatively estimated costs to the public health system of CAN$560 000 per year and CAN$9546.36 per bariatric tourist in Alberta alone. Their findings confirm those of an earlier study that reported bariatric tourism can create substantial costs for the Canadian health system.2

The CBC Radio program *The Current* recently featured an Alberta patient who wished to lose 35 pounds in order to improve her health.3 Because the patient was not sufficiently overweight according to the province’s standards, she did not qualify for bariatric surgery domestically. Instead, she travelled to Mexico to obtain surgery and paid for it out of pocket. The patient told *The Current* that the medical tourism facilitation company that arranged her treatment advised her to do her own research online and informed her that, while there is risk involved with any bariatric surgery, the risk of complications were greater in Canada and less than 1% at the Mexican facility.

Following her surgery, the patient experienced leakage from her stomach while still in Mexico but was eventually discharged to return to Alberta. Back home, she sought medical help, and it was discovered that the leakage had turned septic. The patient was near death, and much of her stomach was removed. She has since experienced considerable weight loss, expects soon to be placed on a feeding tube, and has been advised that she has lost 10 years of life expectancy. The patient expressed regret for her decision to go abroad because of its effects on her health and also because of the costs of her treatment for the Canadian health system. Estimating these costs at CDN $750 000 or higher, she told *The Current*, “what I did was wrong,” and “I apologize to the Canadian citizens for what it cost for tax dollars.”3 The patient’s experience...
highlights the types of negative outcomes from bariatric tourism examined by Kim and colleagues.¹

What should we make of this apology to Canadian taxpayers, and more generally, how should we assign responsibility for the expenses created by bariatric tourists who experience postoperative complications that must be addressed upon their return to Canada? We believe, in fact, this question is quite ethnically challenging.⁴ First, the motivation behind an individual’s decision to travel abroad for care must be assessed.⁵ As Kim and colleagues¹ note, wait times for bariatric surgery are substantial and can impose costs on the health and quality of life of Canadians waiting for surgery. In these cases, bariatric tourists are arguably not being provided timely medical care that is essential to their health and may feel justified in their decision to go abroad. These motivations can be contrasted to those of individuals who are less clearly in need of bariatric surgery. For example, the patient interviewed on The Current noted a more responsible choice in hindsight would have been to seek weight loss through exercise and better nutrition.³ It could be argued that bariatric tourists seeking nonessential care have to bear some responsibility for the expenses created by any complications they experience. However, responsibility for these costs should not be laid solely at the feet of bariatric tourists — even those who seek nonessential care. As publicly funded health systems must ration care according to their available resources, failure to provide access to patients with nonessential cases is less ethically problematic, but we should be asking ourselves whether these patients have received adequate advice and support from the Canadian health system and from their communities to help them make healthy lifestyle choices, including diet and exercise. Local barriers to a healthy lifestyle, including abundant unhealthy food options, unsafe access to exercise and insufficient promotion of healthy living, can exist. Thus, for bariatric tourists with nonessential cases we need to examine the communities and supports to assess their responsibility for the consequences of seeking bariatric surgery abroad.

Finally, we should assess the responsibility of those who facilitate and provide bariatric surgery abroad. The patient interviewed on The Current was largely left on her own to research risks and was then given questionable information on the relative risks of receiving bariatric surgery in Canada compared with a facility in Mexico. While medical care, including bariatric surgery, can be of high quality throughout the world, it is clear that this patient’s case was not a success. We do not believe that in private health care the rule of caveat emptor should hold. Rather, medical professionals have a responsibility to give high-quality care, and both providers and facilitators have a responsibility to give accurate information to patients about the risks associated with their care.

Assigning responsibility for the costs of complications stemming from bariatric tourism is complicated and contextural. We should not simply stop at the point of blaming those who travel abroad for care. Rather, as we argue, there is plenty of blame to go around for these costs to the Canadian health system.

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References

Western University (No. 10 Canadian Stationary Hospital and No. 14 Canadian General Hospital): a study of medical volunteerism in the First World War

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The Canadian government depended on chaotic civilian volunteerism to staff a huge medical commitment during the First World War. Offers from Canadian universities to raise, staff and equip hospitals for deployment, initially rejected, were incrementally accepted as casualties mounted. When its offer was accepted in 1916, Western University Hospital quickly adopted military decorum and equipped itself using Canadian Red Cross Commission guidelines. Staff of the No. 10 Canadian Stationary Hospital and the No. 14 Canadian General Hospital retained excellent morale throughout the war despite heavy medical demand, poor conditions, aerial bombardment and external medical politics. The overwhelming majority of volunteers were Canadian-born and educated. The story of the hospital’s commanding officer, Edwin Seaborn, is examined to understand the background upon which the urge to volunteer in the First World War was based. Although many Western volunteers came from British stock, they promoted Canadian independence. A classical education and a broad range of interests outside of medicine, including biology, history and native Canadian culture, were features that Seaborn shared with other leaders in Canadian medicine, such as William Osler, who also volunteered quickly in the First World War.

On 14 August 1914, an ultimatum that the British government had issued to Germany regarding Belgian sovereignty expired. Britain and its dominions were drawn into the First World War. Despite months of rising international tension, most people and their governments had hoped for resolution and had failed to prepare. In Canada, efforts to raise an army of half a million souls began immediately. Only Sam Hughes, the Minister of Militia and Defence, had prepared by extending the militia, earning the nickname “Drill Hall Sam.” The government now relied on Hughes’ chaotic plan to raise a reserve force as it cancelled the mobilization plan that had been made by its professional military staff. London, Ont., was critical to Hughes’ plan to mobilize volunteers of British stock. It was designated as the headquarters of Canada Military District No. 1. It recruited and trained more than 50 000 troops from the region. A camp at Valcartier, Que., was quickly constructed to mould volunteers from all over Canada into an expeditionary army. Two stationary hospitals were recruited in Valcartier. A third hospital, designated the No. 3 Canadian Stationary Hospital, was raised in London. Its commanding officer was Lieutenant-Colonel Henry Raymond Casgrain, a surgeon in Windsor, Ont., who had been a senior officer of the No. 2 Field Hospital in the 1885 North West Rebellion. Western University’s offer to raise another 200-bed hospital was declined by Hughes on the reasonable basis that sufficient opportunities to volunteer were available locally. Several members of faculty at Western University enlisted, including surgeon John Cameron Wilson, an associate professor of surgical anatomy and lecturer in surgery. Hughes also probably did not want to lessen his control, as he declined McGill University’s offer at the same time. As war was prolonged and casualties mounted, Hughes relented to external pressure, and hospitals were recruited from universities, initially from McGill University, the
University of Toronto and Queen’s University. On Apr. 28, 1916, the Canadian Government asked Western University to raise and equip a 400-bed hospital for deployment.

The request set off a frenzy of activity that saw the hospital ready within a remarkable 2 and a half months. Western Chair of Anatomy and professor of clinical surgery, Edwin Seaborn, long an advocate of deploying a university hospital, was appointed commanding officer at the rank of lieutenant colonel. He led all aspects of recruitment, preparation and training (Appendix 1, available at canj surg.ca). He contacted Western medical alumni, practitioners and nurse graduates from local hospitals, and by May 2, 1916, had 70 offers for the 10 medical officer positions and 60 applications for the 27 nursing positions. Sarnia General Hospital superintendent of nursing, Helena Elizabeth Dulmage, was appointed matron. Virtually none of these volunteers had military experience with the exception of Major John Cameron Wilson, who was transferred back to the Western unit. He brought with him his new wife, nursing sister Lieutenant Bertha Wilson (née Cromwell), a veteran of No. 1 Canadian General Hospital. Seaborn and Dulmage accepted Mrs. Wilson, removing a bar against married women. Another 118 ranks were selected among locals with appropriate trade and military experience, including several medical students with part-time military training on campus. One of the latter was Scott Braithwaite, the university president’s son. Equipment for the hospital was obtained with the help of the local Red Cross, using Canadian Red Cross Commission guidelines and a local church for storage. A university fund drive was started, raising 30 000 pounds (equivalent to Can$4 million at the time) by January 1917. Eventually 90 000 items were packed into 478 boxes for transport.2

The unit arrived in Shorncliffe, England, on Aug. 30, 2017, into a maelstrom of Canadian medical politics. The unit was inspected by Major General Guy Carelton Jones, director general of medical services, and was given a pass on attending a course for new units at the training depot. The unit was first appointed to a small hospital in Seaford, but soon Ravenscroft hospital was added to their responsibility so that they were looking after 450 patients at 4 sites.3 Seaborn appealed to the university fund and purchased an ambulance. Seaborn dealt with outbreaks of infectious diseases, including mumps, measles and meningitis, by using the satellite sites as isolation for specific infections. Meanwhile Carelton Jones had been fired by Hughes on the basis of a naive and probably biased report written by Herbert Bruce. Seaborn claimed that the confusion covered No. 10’s learning curve and that they soon distinguished themselves by never complaining.4 Seaborn was given command of the hospital at Eastbourne in addition to their 4 satellite sites. Looking after 700 beds, they were reconstituted as the No. 14 Canadian General Hospital. Services were added, including radiology, blood transfusion and physiotherapy. Seaborn, whose father-in-law, was the celebrated psychiatrist Maurice Bucke, had included a psychiatrist on the unit’s staff. An academic focus was maintained with 3 meetings weekly to discuss topics in medicine and surgery.

In December 1917, command of the No. 14 was transferred to Lieutenant-Colonel Kenneth Douglas Panton, while Seaborn was tasked with taking a smaller group as the No. 10 Canadian Stationary Hospital to Calais, France. They were given a poor site by the Canal de Marck, which had been abandoned by a British hospital. They arrived to find the camp flooded, with no power. Although about 40 miles from the front at that time, they were subject to aerial bombardment because of the importance of the Calais port. The unit immediately set about rehabilitating the site by installing sewage, drainage, walkways and power, reinforcing patient areas and building bomb shelters. Soon they were receiving up to 250 new patients a day. The canal was used to transport the wounded. Seaborn noticed that the less injured arrived first. He developed a rapid admission system (canal to ward in less than 1 min) so that he could keep treatment areas clear. A mobile surgical unit was created to treat patients injured by bombardment on site. Major General Carelton Jones complimented the unit,
saying that they had achieved in 1 month what the Imper­
ials could not do in 6. The German offensive drive in
March 1918 rendered the forward hospitals inoperative,
dramatically increasing the number and severity of casual­
ties. Most of the patients were British, as the Canadians
were deployed far south of the hospital. The unit received
an order to make a plan to abandon camp. Fortunately the
German offensive failed, and soon the front line was pushed
eastward. Other challenges ensued, including influenza. In
1 tent of 50 patients, 48 men died. Finally on Nov. 11,
1918, came the armistice, and the Calais lighthouse shone
at full power. Within the week there were no more air-raid
precautions or wounded coming in from the front. The
unit did not leave France until Apr. 16, 1919. While in
Calais, No. 10 had admitted 16 712 patients; only 3 other
hospitals in France had taken so many.

Edwin Seaborn was the son of an Anglican minister who
lectured in chemistry at the university. The Seaborns spent
summers by Georgian Bay, where Edwin roamed free in
nature and made friends with the boys of the Saugeen First
Nation. He graduated in medicine from Western Univer­
sity in 1895. There is no record of his postgraduate educa­
tion, but he credited Chicago surgeon, John B. Murphy
with teaching him wound débridement and irrigation, a
method he mandated in the unit. He used his time in
France from armistice until demobilization to pursue
research into the reproductive cycle of the horse with Pro­
fessor Paul Christian Champy in Paris. While he main­
tained a successful surgical practice in London, Ont., after
the war, he continued his equine research and he described
several new species of freshwater fish in Lake Huron. He
made some of the only recordings of native medicine songs
with the help of friends from the Saugeen First Nation. He
was a noted local historian. Seaborn shared his background,
education and life interests with a more famous leader of
Canadian medicine who also volunteered unreservedly in
the First World War: William Osler.

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London, Ont., (Istl, McAlister); and the Royal Canadian Medical Ser­
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Competing interests: None declared.

Contributors: Both authors contributed substantially to the concep­
tion, writing and revision of this article and approved the final version
for publication.

References

1. Hyatt AMJ, Geddes Poole N. Battle for Life. Waterloo (Ont.): Wilfred
2. Seaborn E. History of the No. 10 Stationary Hospital of the Medical Faculty,
University of Western Ontario (1919). London (Ont.): Western Univer­
sity Archives and Research Collection Centre (ARCC LE3.W53M44).
University Archives and Research Collection Centre (AFC Box 20-9,
Seaborn Collection).
4. War diaries – 14th Canadian General Hospital. RG9, Militia and
Defence, Series III-D- 3, Volume 5036, Reel T-10927, File: 859,
Use of intraosseous devices in trauma: a survey of trauma practitioners in Canada, Australia and New Zealand

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Background: Although used primarily in the pediatric population for decades, the use of intraosseous (IO) devices in the resuscitation of severely injured adult trauma patients has recently become more commonplace. The objective of this study was to determine the experience level, beliefs and attitudes of trauma practitioners in Canada, Australia and New Zealand regarding the use of IO devices in adult trauma patients.

Methods: We administered a web-based survey to all members of 4 national trauma and emergency medicine organizations in Canada, Australia and New Zealand. Survey responses were analyzed using descriptive statistics, univariate comparisons and a proportional odds model.

Results: Overall, 425 of 1771 members completed the survey, with 375 being trauma practitioners. IO devices were available to 97% (353 of 363), with EZ-IO being the most common. Nearly all physicians (98%, 357 of 366) had previous training with IO devices, and 85% (223 of 261) had previously used an IO device in adult trauma patients. Most respondents (79%, 285 of 361) were very comfortable placing an IO catheter in the proximal tibia. Most physicians would always or often use an IO catheter in a patient without intravenous access undergoing CPR for traumatic cardiac arrest (84%, 274 of 326) or in a hypotensive patient (without peripheral intravenous access) after 2 attempts or 90 s of trying to establish vascular access (81%, 264 of 326).

Conclusion: Intraosseous devices are readily available to trauma practitioners in Canada, Australia and New Zealand, and most physicians are trained in device placement. Most physicians surveyed felt comfortable using an IO device in resuscitation of adult trauma patients and would do so for indications broader than current guidelines.

Contexte : Bien que le dispositif de perfusion intraosseuse soit depuis des décennies utilisé principalement chez les enfants, son utilisation lors de la réanimation d'adultes victimes de trauma grièvement blessés a récemment gagné en popularité. Notre étude vise à déterminer le niveau d’expérience, les croyances et les attitudes des spécialistes en traumatologie canadiens, australiens et néo-zélandais en ce qui concerne l’utilisation de ces dispositifs chez des patients adultes victimes de trauma.

Méthodes : Nous avons fait parvenir un sondage Web à tous les membres de 4 organisations nationales de traumatologie et d’urgence au Canada, en Australie et en Nouvelle-Zélande. Les réponses ont été analysées au moyen de statistiques descriptives, de comparaisons univariées et d’un modèle à cotes proportionnelles.

Résultats : Au total, parmi les 1771 personnes visées, 425 ont répondu au sondage, dont 375 spécialistes en traumatologie. De tous les répondants, 97 % avaient accès à un dispositif de perfusion intraosseuse, et le modèle EZ-IO était le plus répandu. Presque tous les médecins (98 %) avaient été formés pour utiliser cet appareil, et 85 % d’entre eux l’avaient déjà utilisé chez des adultes victimes de trauma. De plus, la plupart des répondants (79 %) étaient très à l’aise de poser un cathéter intraosseux dans la voie tibiale proximale. La plupart auraient toujours ou souvent recours à ces cathéters pour traiter un patient sans accès intraveineux subissant des manoeuvres de réanimation à la suite d’un arrêt cardiaque traumatique (84 %) ou un patient hypotendu (aucun accès veineux périphérique) sur lequel on a tenté à 2 reprises ou pendant 90 s d’établir un accès vasculaire (81 %).

Conclusion : Les spécialistes en traumatologie canadiens, australiens et néo-zélandais ont facilement accès à des dispositifs de perfusion intraosseuse, et la plupart d’entre eux ont été formés sur leur mise en place. La plupart des répondants au sondage se sont dits à l’aise d’utiliser le dispositif lors de la réanimation d’adultes victimes de trauma et prêts à s’en servir pour traiter des cas plus variés que ce que recommandent les lignes directrices actuelles.
The use of intraosseous (IO) devices for the purposes of achieving vascular access in adults has rapidly expanded in recent years and may still be underutilized. While clinical use of IO devices over the last few decades has been largely confined to pediatric resuscitation, the use of IO devices in adults dates back to the early 20th century and was common during World War II. However, the advent of the over-the-needle plastic catheter in 1950 heralded the age of the peripheral intravenous (IV) cannula, and the use of IO infusions faded. The utility of IO access in pediatrics resurfaced in the 1980s and was introduced into the American Heart Association pediatric resuscitation guidelines in 1985. There were considerable limitations to the IO needles available at the time, until various manufacturers began producing new devices in the late 1990s. These devices included the FAST1 (Fast Access for Shock and Trauma, Pyng Medical Corporation) in 1997, the BIG (Bone Injection Gun, WaisMed) in 1998 and the EZ-IO (Vidacare Corporation) in 2004.

The evolution of IO devices into an easy-to-use, rapidly placed and widely available method of achieving vascular access has made IO placement the emergent vascular access method of choice in the viewpoint of many. Furthermore, prospective studies have demonstrated superior speed of insertion with IO devices compared with the central venous catheter, which is generally considered the back-up technique for failed peripheral IV attempts. Although the use of IO devices is rapidly expanding for patients requiring fluid and cardiac resuscitation, some have expressed concern about their safety, especially in the setting of blood product transfusion. Despite these concerns, the European Resuscitation Council Guidelines, the American Heart Association Advanced Cardiac Life Support (ACLS) and the American College of Surgeons Advanced Trauma Life Support (ATLS) all support the use of IO devices for adult patients in extremis.

Intraosseous devices are currently being used in diverse settings, such as prehospital, the resuscitation bay and in-patient medical emergency settings. The purpose of this study was to investigate how physicians in Canada, Australia and New Zealand feel about using IO devices for resuscitation in adult trauma patients, how often they use these devices in their practices, and whether any physician characteristics are associated with choosing to use an IO device in various clinical scenarios. We hypothesized that IO devices are commonly being used for resuscitation in adult trauma patients.

**Methods**

**Survey design and population**

We conducted an electronic survey to assess the clinical experience and opinions of physicians in Canada, Australia and New Zealand regarding use of IO devices for resuscitation in trauma patients. After obtaining approval from the respective national organizations, the Trauma Association of Canada (TAC), the Canadian Association of Emergency Physicians (CAEP), the Australasian Trauma Society (ATS) and the Australia and New Zealand Association for the Surgery of Trauma (ANZAST), members were contacted via email and invited to participate in the survey via web link. The email explained how members were identified to participate in the survey, described the goals of the study, and assured them that the survey was confidential and that their participation would be anonymous. Owing to the voluntary nature of the study, we considered informed consent to be implied by completion of the survey. Because we sent participants a unique email link, they had the ability to complete the survey only once. This study was endorsed by the TAC Research Committee and received Health Research Ethics Board approval from the University of Alberta in Edmonton, Alta.

**Survey administration and content**

The survey was constructed by the research team using SelectSurvey (www.selectsurvey.net) and refined through pilot testing with multiple trauma researchers for content and response process validity. We are integrally involved in and provide content expertise in the field of trauma research. The survey was sent electronically to all members of TAC, CAEP, ATS and ANZAST. A reminder email was sent 2 weeks after the initial email. The survey was conducted over a 2-month period from April to June 2014.

We collected demographic information on practitioner roles and specialties, their practice and their level of training. Prior training with an IO device included ATLS 8th edition, ATLS 9th edition, Pediatric Advanced Life Support (PALS), accredited physician continuing medical education courses, departmental/hospital courses and training from a clinical nurse educator or colleague. We also collected data on clinical experience with IO devices and comfort levels using these devices. We evaluated the comfort level of physicians with placing an IO catheter in different body regions (proximal tibia, distal tibia, humerus, sternum) using a 4-point Likert scale ranging from “very comfortable” to “not at all comfortable.” Physicians were presented a variety of routes (IO, peripheral IV via gravity flow, peripheral IV via level 1/rapid infuser, central line, saphenous vein cutdown) and asked to indicate which were acceptable for administering blood products, crystalloids, medications or vasopressors by responding “yes,” “no,” or “I don’t know.” Using a 5-point Likert scale ranging from “always” to “never,” we assessed the attitudes of physicians regarding acceptable indications for using an IO catheter in adult/pediatric major trauma patients.

We also presented physicians with a clinical scenario and asked them to select the method they would use to

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establish access to the patient’s vascular system. We asked physicians to select the method they would use on their first attempt and, if unsuccessful, on their second, third, fourth, fifth and sixth attempts. The clinical scenario was as follows:

A 28-year-old male motorcyclist has been involved in a highway speed head-on collision with a truck. He is transported from the scene to your emergency department via ambulance, arriving 20 minutes after the crash. On exam, he has an unstable pelvic fracture, a large right hemotorax, and peritonitis with a distended abdomen. His vital signs are blood pressure 80/48, heart rate of 132, respiratory rate of 28, oxygen saturation of 96% on 15 L via mask, with a Glasgow Coma Score of 11. Emergency Medical Services have attempted to establish peripheral IVs but have been unsuccessful and he currently has no IV access.

Statistical analysis

Data collected through the survey instrument were entered into a Microsoft Excel spreadsheet. Data from partially completed surveys were included in the analysis. We grouped the responses in 2 ways: by physician type (emergency medicine physicians, surgeons, non–emergency medicine physicians [e.g., anesthesiologists, intensivists]) and by regional member organization (CAEP, TAC, ATS, ANZAST). We used simple descriptive statistics to report physician demographics and clinical experience with IO devices. The variable of interest was the attitudes of physicians toward using an IO device to establish vascular access in adult trauma patients. A proportional odds model was fitted using the following explanatory variables: previous IO device training, prior experience with IO devices for vascular access purposes, having access to an IO device, ATLS 8th edition certification, ATLS 9th edition certification and PALS certification. Associations were expressed as odds ratios (ORs) and 95% confidence intervals (CIs). All analysis was performed using SPSS Statistics software version 21 (IBM).18

RESULTS

Of the 1771 members who received the survey invitation, we received responses from 425 (24%) participants. Of these, 356 surveys were fully completed and 69 had 1 or more incomplete questions. The response rates among individual organizations were 26% (61 of 239) for TAC, 24% (322 of 1320) for CAEP and 20% (42 of 212) for ATS/ANZAST. For the purposes of our analysis, we included only surveys that were returned by staff or attending physician trauma practitioners, which left us with 375 responses. By physician type, most respondents were in the emergency medicine group (85%, 320 of 375), followed by the surgeon (8%, 30 of 375) and non–emergency medicine (7%, 25 of 375) groups. The majority of respondents practised in Canada (CAEP and TAC: 93%, 349 of 375; ATS and ANZAST: 7%, 26 of 375). Characteristics of study participants regarding their practices, previous IO training and having access to an IO device are summarized in Table 1.

Most physicians had at least 10 years of experience (56%, 208 of 371). Nearly half of respondents (48%, 179 of 371) practised as trauma team leaders (TTLs), with about 83% (25 of 30) of the surgeon group and 80% (20 of 25) of the ATS/ANZAST group doing so. ATLS certification was reported by 71% (264 of 370) of respondents, with 39% (146 of 370) having completed the 9th edition ATLS provider course. PALS certification was reported by 46% (169 of 368) of physicians, with the surgeon group having the lowest rate (10%, 3 of 30). Almost all respondents (98%, 357 of 366) had previous IO placement training, and only 3% (10 of 363) indicated they did not have access to an IO device. The most commonly available IO device was the EZ-IO, which was available to 83% (292 of 352) of Canadian respondents and 82% (23 of 28) of respondents from Australia and New Zealand. Overall, 72% (263 of 365) of respondents reported ever placing an IO device for the purpose of vascular access in a trauma patient, with 73% (248 of 340) of Canadians compared with 60% (15 of 25) of Australia/New Zealand respondents reporting so. Surgeons reported the highest rate of previous experience with IO devices for vascular access at 80% (24 of 30) compared with 72% (223 of 310) for emergency medicine physicians and 64% for non–emergency medicine physicians. Among Canadian respondents, 87% (213 of 246) reported having placed an IO device within the last year compared with 67% (10 of 15) of Australia/New Zealand respondents. Overall, 85% (223 of 261) of physicians had placed an IO device for the purpose of vascular access within the past year, with 55% (143 of 261) reporting they had done so at least twice during that period.

The comfort level of physicians with placing an IO device at various locations (proximal tibia, distal tibia, humeral head, sternum) is shown in Figure 1. Most physicians (79%, 285 of 361) were very comfortable placing an IO catheter in the proximal tibia, but most (51%, 183 of 361) were somewhat or not at all comfortable placing an IO catheter in the humeral head. The sternum was the location where physicians felt least comfortable placing an IO device, with 59% (212 of 361) responding they were not at all comfortable.

Physicians were presented with a clinical scenario of a severely injured motorcyclist and asked to rank their preferred methods for establishing IV access (Fig. 2). Most physicians (87%, 289 of 331) selected a peripheral IV as the first method they would attempt, followed by an IO device (10%, 34 of 331). If their first attempt was unsuccessful, using a peripheral IV remained the preferred choice for the second attempt (43%, 142 of 331), followed closely by using an IO device (39%, 129 of 331). By the
third attempt, the majority of physicians (56%, 186 of 330) would use an IO device to establish vascular access, followed by ultrasound-guided central IV (17%, 55 of 330). We asked physicians to consider the acceptability of administering blood products, crystalloids, medications, or vasopressors through various routes in a trauma patient. As shown in Figure 3, nearly all physicians believed that infusing crystalloids via an IO device was acceptable (emergency medicine group: 100%, 277 of 277; non–emergency medicine group: 95%, 19 of 20; surgeon group: 100%, 30 of 30). Most physicians also felt it was acceptable to give blood products using an IO device (emergency medicine

<p>| Table 1. Characteristics of survey participants, by physician type and by organization |
|-------------------------------------|------------------|------------------|------------------|------------------|------------------|
| Characteristic                      | Physician group; no. (%)* | Organization; no. (%)* |
|-------------------------------------|------------------|------------------|------------------|------------------|------------------|</p>
<table>
<thead>
<tr>
<th>Years in their role, no. of respondents</th>
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<th>Non-EM</th>
<th>Surgeons</th>
<th>ATS/ANZAST</th>
<th>CAEP/TAC</th>
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<td>70 (20)</td>
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<td>76 (22)</td>
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<td>7 (2)</td>
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<td>5 (17)</td>
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<td>9th edition</td>
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<td>3 (12)</td>
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<td>30</td>
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<td>32</td>
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ANZAST = Australia and New Zealand Association for the Surgery of Trauma; ATLS = Advanced Trauma Life Support; ATS = Australasian Trauma Society; CSEP = Canadian Association of Emergency Physicians; EM = emergency medicine; FAST1 = Fast Access for Shock and Trauma; IO = intraosseous; PALS = Pediatric Advanced Life Support; TAC = Trauma Association of Canada; TTL = trauma team leader.

*Not all physicians answered every question.
†Some physicians selected more than 1 of the choices.
Fig. 1. Comfort level of physicians with placing an intraosseous (IO) device at various locations (proximal tibia, distal tibia, humeral head, sternum). EM = emergency medicine.

Fig. 2. Physicians’ rankings of preferred methods for establishing intravenous (IV) access in a clinical scenario of a severely injured motorcyclist. CCV = conventional central vein; CPV = conventional peripheral vein; IO = intraosseous; SV = saphenous vein cutdown; USCV = ultrasound-guided central vein; USPV = ultrasound-guided peripheral vein.
Fig. 3. Physicians’ perceived acceptability of administering blood products, crystalloids, medications, or vasopressors through various routes in a trauma patient. EM = emergency medicine.

Fig. 4. Overall physician impressions of when to use an intraosseous (IO) device in the setting of an adult trauma patient. CPR = cardiopulmonary resuscitation; IV = intravenous.
group: 96%, 267 of 277; non-emergency medicine group: 85%, 17 of 20; surgeon group: 87%, 26 of 30). Physicians were least comfortable infusing either medications or vasopressors via an IO route (82%, 267 of 327), with 63% (19 of 30) of surgeons, 70% (14 of 20) of non-emergency medicine physicians, and 84% (234 of 277) of emergency medicine physicians believing this was acceptable. Owing to the small number of ATS/ANZAST responses to this question, we were unable to meaningfully compare the results according to organization.

Figure 4 summarizes overall physician impressions of when to use an IO device in the setting of an adult trauma patient. More than 75% of respondents believed that an IO device would “always” or “often” be indicated in the following scenarios: in patients undergoing CPR for traumatic cardiac arrest (84%, 274 of 326); in patients who are hypotensive, without peripheral IVs, after 2 attempts (79%, 257 of 326); and in patients who are hypotensive, without peripheral IVs, after 90 s of trying to establish vascular access (74%, 241 of 326). Furthermore, 81% (264 of 326) of respondents replied that an IO device is indicated “always/often” in a hypotensive patient without peripheral IVs and after 90 s of trying to establish vascular access, and 68% (222 of 326) said an IO device is indicated in the setting of a patient with multiple injuries.

We used a proportional odds model to identify physician characteristics associated with an increased likelihood of an IO device being used. As shown in Table 2, physicians who had previous IO device training (OR 4.02, 95% CI 1.06–15.34, p = 0.040), prior experience with IO devices for vascular access purposes (OR 1.80, 95% CI 1.09–2.99, p = 0.020) and PALS certification (OR 2.07, 95% CI 1.32–3.26, p = 0.001) were more likely to use an IO device. Interestingly, having ATLS certification (8th or 9th edition) was not significantly associated with increased likelihood of using an IO device.

**DISCUSSION**

Our study demonstrates that IO devices for the purpose of vascular access are widely available and are being actively used to resuscitate trauma patients in Canada, Australia and New Zealand. While the literature is replete with studies examining the use of IO devices in various settings (prehospital,16 resuscitation,1 in-patient,17 military19), it isn’t clear exactly how widely implemented this technique is in each setting. For instance, in Canada, the availability of IO devices in the prehospital setting varies among provinces. However, our responses indicate that IO devices are commonly available and used in the emergency department setting.

Our respondents were most comfortable placing the IO device in the proximal tibia. The benefit of this location is quicker time to insertion,20 although time to peak medication concentration is slower than via the sternal route.21 Flow rates via the tibia are also slower than via the humerus.22 Tibial placement is also a subdiaphragmatic point of vascular access, which is not the preferred location23 as blood return to the heart from this infusion point can be thwarted by other potential injuries (e.g., lower-extremity injuries, pelvic fractures, major intra-abdominal injuries). For these reasons, just as the subclavian vein is the preferred insertion site for a central venous catheter in trauma, the humerus may be the preferred IO route in trauma. Additional training focusing on the humerus as an insertion site could be considered.

Current resuscitation guidelines from the American Heart Association and the European Resuscitation Council state that the IO route is an effective method for administering drugs in adults and that it may be used if peripheral IV access cannot be readily established.12,14 The most recent ATLS manual states that IO access can be used in all age groups and suggests that in children 2 attempts at peripheral IV access can be made before resorting to IO devices; however, the manual doesn’t make any such statements regarding the adult population. The respondents in our survey clearly felt comfortable expanding the indications for IO placement, and one-third responded that they consider it to be the vascular access modality of first choice in trauma patients with multiple injuries. In comparison, in a 2009 survey of American emergency medicine residency program directors regarding unstable patients requiring emergent vascular access, 62% chose central line insertion as their second-line choice (after peripheral IV), and IO access became the dominant choice only if a fourth attempt was required.24

The vast majority of our respondents felt it acceptable to transfuse blood products and crystalloids via IO access, with slightly fewer respondents in favour of administering medications or vasopressors using this method. Despite a recent article making a theoretical argument to the contrary,12 there exists a preponderance of historical and recent combat data15 supporting the transfusion of blood products via the IO route. Lewis and Wright19 recently reported on more than 1000 IO devices used in the combat setting of Afghanistan and the overall transfusion of

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATLS 8th edition</td>
<td>0.85 (0.47–1.53)</td>
<td>0.60</td>
</tr>
<tr>
<td>ATLS 9th edition</td>
<td>0.66 (0.38–1.11)</td>
<td>0.12</td>
</tr>
<tr>
<td>PALS</td>
<td>2.07 (1.32–3.26)</td>
<td>0.001</td>
</tr>
<tr>
<td>Previous IO device training</td>
<td>4.02 (1.06–15.34)</td>
<td>0.040</td>
</tr>
<tr>
<td>Experience with IO devices for vascular access purposes</td>
<td>1.80 (1.09–2.99)</td>
<td>0.020</td>
</tr>
<tr>
<td>Access to an IO device</td>
<td>2.50 (0.61–10.26)</td>
<td>0.20</td>
</tr>
</tbody>
</table>

ATLS = Advanced Trauma Life Support; CI = confidence interval; IO = Intraosseous; OR = odds ratio; PALS = Pediatric Advanced Life Support.
1881 units of packed red blood cells, 1497 units of fresh frozen plasma, 619 units of platelets and 410 units of cryoprecipitate with no major complications. The translation of lessons learned from military combat into civilian practice is often delayed; however, evidence supporting the administration of medications via the IO route is mounting. The responses to our international survey provide evidence that IO devices are readily available and being used for resuscitation purposes and suggest that there is an opportunity to educate IO practitioners and train them to make sound and competent judgments regarding the use of these devices in adult trauma patients.

Our search of the contemporary literature revealed only 3 published surveys examining IO use. Hallas and colleagues surveyed Scandinavian emergency physicians, anesthesiologists and pediatricians to assess users’ experiences of complications with IO placement. In 68% of cases the user reported a complication or difficulty using the IO device, raising the concern that perceived difficulties with IO insertion could affect the willingness of medical staff to use IO devices. This finding suggests there is a need for improved device insertion education. In 1999, Lavis and colleagues surveyed members of the British Association for Accident and Emergency Physicians on their familiarity with and use of IO devices. While 74% responded they were aware that IO devices could be used in adult resuscitation, only 7% reported using the technique. James Cheung and colleagues performed an electronic survey of residents and attending physicians from a variety of specialties at a Canadian hospital in an effort to uncover barriers and facilitators to IO placement in adult resuscitations when peripheral IVs could not be achieved. They concluded that in order to increase IO use, future educational interventions should address physicians’ attitudinal, normative and control beliefs. Our results indicate widespread dissemination of the IO technique and significant attitudinal buy-in among physicians on the usefulness of IO devices in the setting of adult trauma resuscitation.

Limitations

There are limitations to our study. With its self-reporting survey design, validity is inherently limited by the response rate. Our response rate was 24%, hence there is the possibility that nonresponder bias may threaten the validity of our findings. Portions of our survey relied on self-reporting of volume and experience; thus, it is subject to recall bias. Given the smaller number of responses from the ATS/ANZAST group compared with the CAEP/TAC component, we were limited in our ability to compare these groups. Despite these limitations, our study has a number of strengths. The survey was designed by experts in the fields of trauma and emergency medicine using a rigorous methodology. The analysis was focused on active staff/attending-level trauma care practitioners, approximately 50% of whom were working as active TTLs. Although the response rate was 24%, this survey represents the opinions of 375 physicians and, to our knowledge, is the largest such survey conducted to date on this topic.

Conclusion

IO devices for the purposes of rapid vascular access are readily available to trauma practitioners in Canada, Australia and New Zealand, and these devices are in fact being used by trained practitioners in caring for trauma patients. Furthermore, the trauma physicians surveyed believed that indications for IO device placement could be expanded beyond current guidelines, and in particular could include the hypotensive adult trauma patient without peripheral IV access after 2 attempts or 90 s trying to obtain access in the setting of traumatic cardiac arrest or in patients with multiple injuries. Future efforts to optimize the use of IO devices in trauma may include local quality care initiatives aimed at encouraging IO device use for these expanded indications with corresponding outcome tracking and assessment.

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Competing interests: None declared.

Contributors: P. Engels, S. Widder and R. Green designed the study. P. Engels, M. Erdogan and K. Martin acquired the data, which P. Engels, M. Erdogan, S. Widder, M. Butler, N. Kureshi and R. Green analyzed. P. Engels, M. Erdogan, S. Widder, M. Butler, N. Kureshi and R. Green wrote the article, which all authors reviewed and approved for publication.

References

9. Davis DP. The use of intraosseous devices during cardiopulmonary resuscitation: Is this the answer for which we have been searching? Resuscitation 2012;83:7-8.


Hypertrophic pyloric stenosis in the Maritimes: examining the waves of change over time

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Background: Changing patterns of referral and management of pediatric surgical conditions, including hypertrophic pyloric stenosis (HPS), have recently been described and often relate to comfort with early nonoperative management, anesthesia and corrective surgery. Travelling distance required for treatment at pediatric centres can also be burdensome for families. We assessed referral patterns for HPS in the maritime provinces of Canada over 10 years to quantify the burden on families travelling for surgical care.

Methods: We reviewed the charts of all patients with HPS in the Maritimes. Length of hospital stay (LOS) and complication rates were analyzed in regards to resuscitation and management at a pediatric centre and/or peripheral centres. We used postal codes for each patient to track distance travelled for management.

Results: We assessed 751 cases of HPS. During the study period (Jan. 1, 2001–Dec. 31, 2010), referral to pediatric centres increased from 49% to 71%. Postoperative complications were 2.5-fold higher in peripheral centres. Infants referred to pediatric centres were 78% less likely to have an LOS longer than 3 days. Laparoscopic pyloromyotomy, which was performed only in pediatric centres, was associated with a shorter postoperative LOS.

Conclusion: Our study supports the current literature demonstrating improved outcomes, shorter overall LOS and decreased risk of complications when infants with HPS are treated in pediatric centres. This should be considered when planning access to pediatric surgical resources.

Contexte : Une évolution des tendances dans les pratiques d’orientation des patients et de prise en charge des affections pédiatriques nécessitant une intervention chirurgicale, telles que la sténose hypertrophique du pylore (SHP), a récemment été décrite; elle dépend souvent du degré d’acceptation de la prise en charge non chirurgicale précoce, de l’anesthésie et de la chirurgie correctrice. Le traitement en centre pédiatrique peut exiger des déplacements pénibles pour les familles. Nous avons évalué les pratiques d’orientation des cas de SHP dans les provinces maritimes du Canada sur une période de 10 ans pour quantifier l’ampleur du fardeau qui incombe aux familles devant voyager pour obtenir des soins chirurgicaux.

Méthodes : Nous avons étudié le dossier de tous les patients atteints de SHP dans les Maritimes et avons comparé la durée de séjour et le taux de complications associés à la réanimation et à la prise en charge dans les centres pédiatrick et les centres périphériques. Nous avons aussi utilisé les codes postaux des patients pour déterminer la distance de déplacement des familles.

Résultats : Nous avons analysé 751 cas de SHP. Pendant la période à l’étude (2001–2010), le taux d’orientation des patients vers les centres pédiatrick est passé de 49 % à 71 %. Les complications postopératoires étaient 2,5 fois plus courantes dans les centres périphériques, et les séjours de plus de 3 jours étaient 78 % moins fréquents chez les nourrissons traités en centre pédiatrique. La pyloromyotomie par laparoscopie, réalisée dans les centres pédiatrick seulement, a été associée à une réduction de la durée de séjour postopératoire.

Conclusion : Notre étude va dans le même sens que la littérature actuelle, qui indique que le traitement des nourrissons atteints de SHP en centre pédiatrick est associé à de meilleurs résultats postchirurgicaux, à une durée d’hospitalisation moins longue et à un risque de complications plus faible que le traitement dans un centre périphérique. Ces résultats devraient être pris en compte dans la planification de l’accès aux ressources dans le domaine de la chirurgie pédiatrick.
C

hanging patterns of referral and management of various surgical conditions have recently been described and often relate to comfort with resuscitation management, infant anesthesia and surgical correction. However, substantial travelling distance to centres offering the appropriate level of care is associated with family stress, increased financial costs and reduction in social supports of the home community. In order to justify this added patient burden, the benefit of primary referral must outweigh the negative aspects.

Hypertrophic pyloric stenosis (HPS) is one of the most common surgical conditions encountered in infants and is unique in its need for adequate preoperative resuscitation in addition to surgical correction. Historically, HPS was a condition managed and corrected in the community by general surgeons as well as surgeons with pediatric subspecialty training. Recent changes in health care deliverables, however, have identified the value of not only pediatric surgical expertise, but also subspecialty expertise in anesthesiology and perioperative care. Subsequent reduction in exposure of surgical trainees to pediatric surgery during postgraduate residency training in recent years has also led to a decrease in comfort with overall HPS surgical management.

The Maritime provinces — Nova Scotia, New Brunswick and Prince Edward Island (PEI) — serve as an excellent “laboratory” in which to examine referral patterns of HPS (Fig. 1). The most populated province, Nova Scotia (population of 913 462 in 2006), has the only pediatric hospital (IWK Health Centre) in the region, which serves all 3 Maritime provinces and is the main site of pediatric surgical expertise. In New Brunswick (population of 729 997 in 2006) and PEI (population of 135 851 in 2006), 4 and 2 large general hospitals, respectively, with dedicated nonsurgical pediatric services offer basic pediatric surgical care by general surgeons, with medical management (including preoperative resuscitation) managed by general pediatricians. In addition, francophone families in northern New Brunswick have historically been referred to the adjacent province of Quebec, where pediatric surgical services are provided at the Centre Hospitalier de l’Université Laval (CHUL).

Our objective was to investigate the patterns of HPS referral changes in the Maritimes over time and correlate these patterns with patient outcomes. We also endeavoured to quantify and correlate the burden on families with referral patterns, as reflected by distance travelled for surgical care.

METHODS

We contacted the medical records departments of all hospitals with pediatric services in the 3 Maritime provinces to identify patients with a discharge diagnosis of HPS during the study period (Jan. 1, 2001–Dec. 31, 2010). Pediatricians or surgeons at each centre with eligible cases were recruited to complete a chart review of such cases. The pediatric hospital in Quebec (CHUL) that takes referrals from New Brunswick was also contacted and queried. Locations of all hospitals involved in the study are shown in Figure 1. This study was approved by the Research Ethics Board of each centre in the study.

Cases included all patients discharged from hospital between Jan. 1, 2001, and Dec. 31, 2010, who had a diagnosis of HPS; a residential address in New Brunswick, Nova Scotia or PEI; and who had a pyloromyotomy (open or laparoscopic). Data included patient name, date of birth, sex, postal code, age at diagnosis, hospital of first admission, hospital of transfer (if transferred to second hospital for surgery), hospital of surgery (coded as pediatric or non-pediatric), date of surgery, overall preoperative length of stay (LOS; defined as time from date of first admission to date of surgery, including LOS at first hospital if ultimately transferred), postoperative LOS (defined as time from surgery to final date of discharge), total LOS (defined as time from date of first admission to final date of discharge) and complications (wound infection, leak, or death). Three management groups were established: group 1 included patients who underwent resuscitation and surgery in a pediatric centre, group 2 included those who underwent initial/all resuscitation in a peripheral centre and surgery in a pediatric centre, and group 3 included patients for whom all management occurred in peripheral centre(s). Two time periods were established: the early period included patients with a surgery date between Jan. 1, 2001, and Dec. 31, 2005, and the late period included those with a surgery date between Jan. 1, 2006, and Dec. 31, 2010. Outcomes of interest included preoperative LOS as a proxy measure in efficiency of resuscitation and accessing operating room services, postoperative LOS as a proxy measure of clinical outcome and complications, and total LOS as a measure of overall efficiency of resource utilization.

To determine the burden on families if cases were referred to 1 of the 2 pediatric centres for surgery, driving
times from the family’s place of residence to the pediatric centre for all patients who ultimately had surgery performed at one of the pediatric centres were stratified by time period. The driving times were calculated using the ODMatric function in the Network Analyst tool in ArcGIS 10.1. We used DMTI route logistic as the network road data for driving time. Geopinpoint software was used to geocode all patients’ postal codes.

**Statistical analysis**

We used descriptive statistics and univariate analyses to determine associations between variables associated with patient management and outcomes of interest. Continuous variables (LOS) were dichotomized at the level of the upper quartile. Unadjusted odds ratios (ORs) of associations were determined using χ² analyses. For the main outcome of interest, total LOS, we applied backward step-wise logistic regression using all variables reaching a level of p < 0.20 to determine the adjusted ORs, with 95% confidence intervals (CIs) not spanning 1.0 and a value of p > 0.05 ultimately considered to be significant. All statistical analyses were performed using SAS statistical software, version 8.2.

**RESULTS**

A total of 751 infants meeting our inclusion criteria were identified during the study period. Forty-seven percent (n = 353) had surgery in the early time period (Table 1). Thirty-seven percent (n = 280) were admitted to the pediatric centre for both resuscitation and surgery (group 1), 23% (n = 173) were transferred to a pediatric centre after resuscitation in a peripheral centre (group 2) and the remaining 39% (n = 296) had resuscitation and surgery in the peripheral centres only (group 3; Table 2).

<table>
<thead>
<tr>
<th>Table 1. Demographic and clinical characteristics of the study sample, by time period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
</tr>
<tr>
<td>Age at diagnosis, mean ± SD, d</td>
</tr>
<tr>
<td>Age at diagnosis, median, d</td>
</tr>
<tr>
<td>Male sex</td>
</tr>
<tr>
<td>Preoperative LOS &gt; 2 d</td>
</tr>
<tr>
<td>Postoperative LOS &gt; 2 d</td>
</tr>
<tr>
<td>Total LOS &gt; 3 d</td>
</tr>
<tr>
<td>Postoperative complications</td>
</tr>
<tr>
<td>Laparoscopic approach</td>
</tr>
</tbody>
</table>

LOS = length of stay in hospital; SD = standard deviation.

*Unless indicated otherwise.

<table>
<thead>
<tr>
<th>Table 2. Clinical characteristics of study sample, by referral group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristic</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>No. of patients</td>
</tr>
<tr>
<td>Preoperative LOS &gt; 2 d</td>
</tr>
<tr>
<td>OR 2.7 (95% CI 1.4–5.0)*</td>
</tr>
<tr>
<td>p = 0.002</td>
</tr>
<tr>
<td>Postoperative LOS &gt; 2 d</td>
</tr>
<tr>
<td>p = 0.24</td>
</tr>
<tr>
<td>Total LOS &gt; 3 d</td>
</tr>
<tr>
<td>OR 2.7 (95% CI 1.8–3.9)</td>
</tr>
<tr>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Postoperative complications</td>
</tr>
<tr>
<td>p = 0.97</td>
</tr>
<tr>
<td>CI = confidence interval; LOS = length of stay in hospital; OR = odds ratio.</td>
</tr>
</tbody>
</table>
| *Unadjusted relative to group 1.
Figure 2 and Figure 3 depict the changes in referral patterns between the 2 time periods, with the proportion of infants having surgery in a pediatric centre increasing from 49% in the early period to 71% in the later period with the inclusion of patients resuscitated in a peripheral hospital. Most of this change appears to have occurred with patients in the 2 Maritime provinces without pediatric centres (New Brunswick and PEI). Despite this, however, there was little apparent change in the proportion of infants undergoing all of their preoperative resuscitation at a pediatric centre. Over the 2 time periods, these findings translated to a 6-fold increase in overall driving times to pediatric centres from the patients’ places of residence (Fig. 4).

Table 2 depicts variations in outcomes relative to the 3 referral pattern groups. All LOS parameters were significantly increased with management in the peripheral centres, whether preoperative resuscitation or surgery. Postoperative complications also increased 2.5-fold with surgery in the peripheral centres.

Table 3 depicts associations with overall longer total LOS beyond 3 days. After adjusting for all covariates, infants who were referred to the pediatric centres for surgery were 78% less likely to have an overall LOS longer than 3 days. Infants with postoperative complications (excluding death) had a 3.2-fold increased risk of a longer LOS. There appeared to be no association between the time period and the overall LOS of these patients. Although protective with univariate analysis, a laparoscopic approach, which was practised at only 1 of the pediatric centres, was associated with a 50% increased risk of a longer overall LOS. This was no longer statistically significant, however, when stratified for time period (p = 0.45 for the early period; p = 0.89 for the later period; data not shown). When only postoperative LOS was considered, logistic regression revealed significant positive associations between postoperative complications and an LOS longer than 2 days (OR 9, 95% CI 4–29), while having surgery in a pediatric centre (OR 0.29, 95% CI 0.1–0.3) and having a laparoscopic procedure (OR 0.33, 95% CI 0.3–0.9) were both significantly protective.

Table 4 depicts associations with postoperative complications. After controlling for covariates, having surgery in a pediatric versus a nonpediatric centre was the only variable that retained significance and was associated with a 3-fold reduced risk of complications.

**DISCUSSION**

Management of HPS in the Maritimes between 2001 and 2010 demonstrated a clinically significant change in practice, with a more than 2.5-fold increase in the proportion of infants undergoing diagnosis and at least initial resuscitation in a nonpediatric centre followed by referral to a pediatric centre for definitive surgical care. This was associated with a significant decrease in the proportion of infants requiring a prolonged postoperative LOS, but no change in the proportion of infants with a prolonged in-hospital LOS overall, likely related to the fact that the proportion of infants undergoing diagnosis and initial resuscitation in peripheral centres changed little between time periods. Although the overall complication rate did not change between time periods, undergoing surgery in a pediatric centre was clearly protective for postoperative complications.
Fig. 3. Changes in referral patterns between the 2 time periods, with geographical distribution of all cases based on postal codes.
McAteer and colleagues found a similar trend in the state of Washington for preferential referral to pediatric centres for appendicitis and HPS between 1987 and 2009. In their study, referral to pediatric centres in Washington was associated with decreased postoperative complications. Lower complication rates associated with treatment in pediatric centres have been demonstrated in multiple other studies, likely attributable to subspecialty training, higher volume and greater experience among all staff. Based on this evidence, all pediatric operations should ideally be performed at specialized pediatric centres. Unfortunately, this can create difficulties in light of Canada’s large geographic distribution.

A few studies have found that general surgeons have similar outcomes and complication rates for appendectomies and pyloromyotomies as long as a minimum number of procedures are performed per year, suggesting that some pediatric surgeries can be performed safely in the community setting. However, risk of complications, especially with pyloromyotomies, is still increased if not performed in a pediatric centre. In addition to surgical experience, the comfort level of anesthesiologists who do not normally treat children must also be taken into account.

Finally, as a result of increases in specialization as well as limitations in trainee work hours, the newer generations of general surgeons have less exposure to infants and children than prior generations, limiting their experience and comfort in the management of this patient population. As a result, the trend of increased referrals of this patient population to regional pediatric centres for surgical care seen in this study will be further exaggerated. In the case of pyloric stenosis in this study, there was no change in immediate referral upon diagnosis, as a similar proportion of infants underwent some or all preoperative resuscitation in the periphery between the 2 time periods. However, shorter preoperative stay observed when all treatment occurred at a pediatric centre suggests that this preoperative resuscitation may be more efficient when done at specialized hospitals. Therefore, immediate transfer upon diagnosis may be more cost-effective and result in better overall outcomes. Adding to the debate of pediatric surgical centralization, Cosper and colleagues found there was a higher hospital cost for patients treated in specialized pediatric centres compared with community settings. For HPS, however, this cost was only 9% above the mean and could be offset by the costs of higher complication rates. Furthermore, alternative approaches more commonly performed at pediatric centres, including periumbilical and laparoscopic pyloromyotomies, can improve cosmesis without increasing complication rates. As seen in other studies, our study found no differences in complication rates or LOS with a laparoscopic approach. This study was not powered to look at this specifically; larger studies examining this specific variable are needed to determine any true effect of a minimally invasive approach to pyloromyotomies.

The mental and physical burden on the patient, as well as the emotional and financial burden of travelling incurred by the family for pediatric surgical care is not to be underestimated. Studies have demonstrated the willingness of parents to travel significant distances for the potential outcome improvements at specialized hospitals. Our study highlights the travel burden (approximated by total kilometers to facility of treatment) families encounter in the Maritimes while relocating for specialized pediatric care. At the IWK Health Centre, local housing resources are made available for parents but likely do not completely eliminate stress on the family, although this was not formally assessed in our study. Further studies focusing on particular family stressors may help identify specific areas for assisted resource allocation for families travelling long distances for pediatric surgical care.

The benefits of lower complication rates, shorter LOS and improvements in overall outcomes associated with management of HPS at pediatric centres imply that all cases of HPS should be primarily referred to a pediatric centre for management. The burden of travel and financial
stress on the family unit, while potentially substantial, is outweighed by the gains in outcomes. These findings were corroborated in studies in Washington and Ontario.6,7

The topic of pediatric surgical regionalization is not a novel concept, and there is substantial evidence to suggest that the majority of pediatric surgery should be performed at pediatric centres to decrease overall morbidity, mortality and LOS. Increased pediatric centre referral is a trend in multiple areas of North America. In order to streamline HPS management, policies requiring referral of all cases of HPS to a pediatric centre for definitive management may be required. These changes may help to allocate funds and resources to offset the burden on families of infants being treated.

**Conclusion**

Our study supports similar observations in the literature of improved outcomes, shorter overall LOS and decreased risk of complications when infants with HPS are referred to a regional pediatric centre for preoperative resuscitation and surgery in the Maritime provinces of Canada. This should be considered when planning access to pediatric surgical resources in other parts of the country to ensure optimal outcomes for all children with HPS. Caution should be taken to not completely limit all pediatric surgery to specialized centres, as this could result in inadequate experience for the management of patients with acute surgical emergencies who cannot afford the time of transfer. National authoritative bodies, such as the British Association of Paediatric Surgeons, have taken steps to develop guidelines to streamline access to appropriate pediatric surgical care services in order to maximize outcomes on individual patient and population levels.20 Development and ongoing evaluation of such guidelines should be considered in Canada and elsewhere.

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**Competing interests:** None declared.

**Table 3. Factors associated with overall longer total LOS beyond 3 days**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Patients with total LOS &gt; 3 d, %</th>
<th>Unadjusted</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative LOS &gt; 2 d</td>
<td>26.4</td>
<td>&lt; 0.001</td>
<td>138 (19–998)</td>
</tr>
<tr>
<td>Postoperative LOS &gt; 2 d</td>
<td>61.3</td>
<td>&lt; 0.001</td>
<td>32 (19–54)</td>
</tr>
<tr>
<td>Late study period (2006–10)</td>
<td>54.1</td>
<td>0.55</td>
<td>1.1 (0.8–1.5)</td>
</tr>
<tr>
<td>Two hospital admissions*</td>
<td>25.8</td>
<td>0.52</td>
<td>1.1 (0.8–1.6)</td>
</tr>
<tr>
<td>Postoperative complications</td>
<td>10.4</td>
<td>&lt; 0.001</td>
<td>4.0 (2.0–7.9)</td>
</tr>
<tr>
<td>Surgery in pediatric centre</td>
<td>44.8</td>
<td>&lt; 0.001</td>
<td>0.26 (0.19–0.36)</td>
</tr>
<tr>
<td>Laparoscopic approach</td>
<td>24.7</td>
<td>0.009</td>
<td>0.70 (0.48–0.90)</td>
</tr>
</tbody>
</table>

CI = confidence interval; LOS = length of stay in hospital; OR = odds ratio.
*Admission and initial resuscitation at 1 hospital followed by transfer to another hospital for surgery. Includes cases with transfer between 2 peripheral centres.
†Unable to include in logistic regression model owing to collinearity with long total LOS.

**Table 4. Factors associated with postoperative complications**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Patients with complications, %</th>
<th>Unadjusted</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resuscitation and surgery in pediatric centre</td>
<td>22.4</td>
<td>0.025</td>
<td>(0.46:0.23–0.92)</td>
</tr>
<tr>
<td>Preoperative LOS &gt; 2 d</td>
<td>18.4</td>
<td>0.23</td>
<td>(1.6:0.7–3.4)</td>
</tr>
<tr>
<td>Late study period (2006–10)</td>
<td>51.0</td>
<td>0.77</td>
<td>(0.9:0.5–1.6)</td>
</tr>
<tr>
<td>Two hospital admissions*</td>
<td>25.8</td>
<td>0.16</td>
<td>(0.6:0.3–1.3)</td>
</tr>
<tr>
<td>Surgery in pediatric centre</td>
<td>44.8</td>
<td>&lt; 0.001</td>
<td>(0.26:0.19–0.36)</td>
</tr>
<tr>
<td>Laparoscopic approach</td>
<td>18.4</td>
<td>0.08</td>
<td>(0.5:0.3–1.1)</td>
</tr>
</tbody>
</table>

CI = confidence interval; LOS = length of stay in hospital; OR = odds ratio.
*Admission and initial resuscitation at 1 hospital followed by transfer to another hospital for surgery. Includes cases with transfer between 2 peripheral centres.
Contributors: J. Creaser and N. Yanchar designed the study. J. Creaser and S. Leclerc acquired the data, which A. Ednie, O. Amram, J. Creaser, N. Schuurman and N. Yanchar analyzed. A. Ednie and N. Yanchar wrote the article, which all authors reviewed and approved for publication.

References

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Updated Nov. 22, 2016.
The use of computer-assisted surgery as an educational tool for the training of orthopedic surgery residents in pedicle screw placement: a pilot study and survey among orthopedic residents

Background: The training of orthopedic residents in adequate pedicle screw placement is very important. We sought to investigate orthopedic residents’ perspectives on the use of computer-assisted surgery (CAS) in a training trial.

Methods: Orthopedic residents were randomly assigned to independently place a screw using the free-hand technique and the CAS technique on 1 of 3 cadavers (Cobb angles 5°, 15° and 67°) at randomly selected thoracolumbar vertebral levels. All residents were blinded to their colleagues’ pedicle screw placements and were asked to complete a short questionnaire at the end of the session to evaluate their experience with CAS. We obtained CT images for each cadaver to assess pedicle screw placement accuracy and classified placement as A) screw completely in pedicle, B) screw < 2 mm outside pedicle, C) screw 2–4 mm outside pedicle, or D) screw > 4 mm outside pedicle.

Results: Twenty-four orthopedic residents participated in this trial study. In total, 65% preferred using the free-hand technique in an educational setting even though most (60%) said that CAS is safer. The main reason for free-hand technique preference was the difficult technical aspects encountered with CAS. In addition, accuracy of pedicle screw placement in this trial showed that 5 screws were classified as A or B (safe zone) and 19 as grade C or D (unsafe zone) using the free-hand technique compared with 15 and 9, respectively, using CAS ($p = 0.008$).

Conclusion: Orthopedic residents perceived CAS as safe and demonstrated improved accuracy in pedicle screw placement in a single setting. However, the residents preferred the free-hand technique in an educational setting owing to the difficult technical aspects of CAS.

Contexte : Il est très important d’apprendre aux médecins résidents en chirurgie orthopédique comment positionner adéquatement une vis pédiculaire. Notre objectif était d’obtenir l’opinion des médecins résidents sur le recours à la chirurgie assistée par ordinateur (CAO) dans un essai sur la formation.

Méthodes : Des médecins résidents en chirurgie orthopédique répartis aléatoirement ont placé indépendamment une vis à l’aide d’une technique à main libre basée sur les repères topographiques et la palpation, et de la CAO dans 1 de 3 cadavres (angles de Cobb de 5°, 15° et 67°) dans une vertèbre dorsolombar sélectionnée aléatoirement. Aucun des médecins résidents n’a pu observer le positionnement de la vis de ses collègues, et les participants ont rempli un court questionnaire à la fin de la séance pour évaluer leur expérience de la CAO. Nous avons obtenu un tomodensitogramme pour chaque cadavre afin d’évaluer la précision du positionnement de la vis pédiculaire, classée selon 4 catégories : A) vis entièrement dans le pédicule, B) vis < 2 mm hors du pédicule, C) vis de 2–4 mm hors du pédicule, ou D) vis > 4 mm hors du pédicule.

Résultats : Vingt-quatre médecins résidents en chirurgie orthopédique ont participé à l’étude clinique. Au total, 65 % d’entre eux ont préféré utiliser la technique à main libre dans un contexte de formation, même si la plupart (60 %) considéraient que la CAO était plus sécuritaire. La principale raison justifiant cette préférence était le degré de difficulté technique associé à la CAO. De plus, une évaluation de la précision du positionnement a montré qu’avec la technique à main libre, 5 des vis posées se classaient dans les catégories A ou B (sécuritaire) et 19 dans les catégories C ou D.
Pedicle screws were first used in the United States by Harrington and colleagues\(^1,2\) to reduce complicated cases of spondylolisthesis. Today, pedicle screw fixations are used for the treatment of many ailments affecting the spine, including vertebral fractures, degenerative disk disease, spine tumours, spondylolisthesis and scoliosis. Pedicle screws used in spine constructs improve the overall spine stability while restoring vertebral height and alignment. In order to maximize biomechanical stability and safety,\(^3\) screws are placed directly within the pedicle of vertebrae. Owing to the proximity of the spinal canal and feeding vessels, pedicle screw misplacement can potentially harm vascular and neural structures.\(^4,5\) Other possible complications associated with pedicle screw placement include instability and nonunion.\(^6-8\)

Pedicle screw placement accuracy differs across spinal regions (e.g., thoracic v. lumbar) and may be increasingly challenging in patients with spine deformity. Studies using conventional surgical techniques have reported pedicle screw misplacement varying between 5\% and 41\% for the lumbar spine and up to 55\% in the thoracic spine.\(^9-12\) As a result, novel image-guided and navigation surgical techniques have been developed to increase the placement accuracy and the safety of pedicle screw insertion. A recent systematic review reported that the rate of pedicle screw placement fully contained in the pedicle (without perforation) using a free-hand technique ranged between 69\% and 94\% compared with the help of fluoroscopy (28\%–85\%), computed tomography (CT) navigation (89\%–100\%) and fluoroscopy-based navigation (81\%–92\%).\(^4\) Therefore, it appears that navigation techniques may improve pedicle screw accuracy compared with free-hand techniques and fluoroscopy. Orthopedic spine surgeons are typically introduced to different navigation techniques throughout their careers. However, as pedicle screw placement accuracy is critical in spine surgery, it may be relevant to introduce these techniques at the residency level. Therefore, the purpose of this study was to evaluate residents’ perceptions of computer-assisted surgery (CAS) and to assess the effectiveness of CAS as a tool for the training of pedicle screw placement among a group of orthopedic residents in an educational trial.

**Methods**

**Sample**

We recruited the residents (postgraduate years [PGY] 1–4) from the McGill University orthopedic surgery program, Montreal, Que., for this research project. The trial study was conducted during a protected teaching day in which all orthopedic residents were expected to be present. The PGY5 residents had an alternative teaching session organized and did not attend the event. Other residents who were on approved leave or who were on post-call days were exempt from the session. We obtained informed consent from all residents who agreed to take part in this study.

**Study settings**

The study was conducted at the Arnold and Blema Steinberg Medical Simulation Centre, McGill University. In order to simulate different levels of difficulty for pedicle screw placement, 3 cadavers with varying degrees of scoliosis (Cobb angles 5°, 15° and 67°) were selected for the purpose of this training session (Fig. 1). Each cadaver was designated to a respective station and dissected by a trained orthopedic spine surgeon (M.W.) to allow for clear identification of anatomic surface landmarks. Each training station, cadaver and vertebral levels were clearly labelled (Fig. 2). Standard pedicle screw placement instrumentation as well as a fully functional Stryker Fluoro Navigation 2D CAS system (Stryker Navigation System, Stryker Leibinger) was provided at each station. All images for CAS were acquired before the start of the study using a GE 9800 C-arm machine. The CAS system accuracy was verified before the start of the educational trial by taking anteroposterior (AP) and lateral radiographs of the spine and verifying the accuracy of the depicted virtual reality tool on the navigation image in relation to the real time position of the tool (spinous processes were used as easy reference points). In addition, the reference tracker was repositioned to ensure that instrumentation at a maximum of 2 levels above or below the reference was used. Radiographs were verified to ensure accuracy for different instrumented levels each time the tracker was repositioned as detailed above.

A trained orthopedic spine surgeon (M.W.) familiar with both standard instrumentation and CAS was present at each station to answer questions regarding instrumentation. Prior to the beginning of the training session, all residents received a brief lecture (30 min) on CAS and free-hand techniques for the placement of pedicle screws. Each resident was then randomly assigned to place 1 screw using the free-hand technique and 1 screw using the CAS technique on 1 of the cadavers at randomly selected vertebral levels.
levels (only thoracolumbar levels were used). The supervisor at each station informed the resident what level to instrument, and all of the residents sequentially placed their 2 screws independently, with no assistance. Only polyaxial screws were used. To minimize visual cues, the head position of the polyaxial screws were altered between

Fig. 1. Cobb angle measurements for each cadaver.

Fig. 2. Cadaver station setup.
residents, thus all residents were blinded to their colleagues’ placement orientation.

At the end of the session all residents completed a short questionnaire regarding their experiences and preferences during the training session, including their preferred technique for educational purposes. The questionnaire also asked which technique they thought was safer and whether they would use navigation in future practice. A later survey was sent to all participants to determine why a technique was their preferred choice, thus giving a global impression of surgical residents’ perceptions of CAS and spine surgery. This survey was sent after pedicle screw results were seen for both free-hand and CAS techniques.

**Computed tomography and grading**

We obtained CT images for each cadaver to assess pedicle screw placement accuracy. Sagittal, coronal and axial cuts were acquired for all instrumented levels using 2.5 mm slices. Based on the CT images, pedicle screw accuracy was classified as follows: A) screw completely in pedicle, B) screw < 2 mm outside of pedicle, C) screw 2–4 mm outside of pedicle, or D) screw > 4 mm outside of pedicle. All screws were scored by the same rater, who verified all 3 planes (sagittal, coronal, axial) to determine the grade. A grade D score was also given to any screw that was dislodged before imaging, as poor placement was assumed to have resulted in screw instability. In accordance with the literature, grade A and B screws were deemed to be within the “safe zone,” whereas grade C and D screws were deemed to be in the “unsafe zone.”

**Statistical analysis**

We used Fisher exact tests to assess the difference in screw placement accuracy between the free-hand technique and CAS method and to evaluate the difference according to the level of residency, the cadaver’s Cobb angles (5º, 15º and 67º) and the instrumented spine region (thoracic v. lumbar). We considered results to be significant at \( p < 0.05 \).

**Results**

A total of 24 residents participated in the study: 3 PGY1, 7 PGY2, 8 PGY3 and 6 PGY4. No residents declined to be a part of the study, thus the rate of participation was 100%.

A total of 48 pedicle screws were inserted by the residents: 24 using the free-hand technique and 24 using CAS. Seventeen of the 24 residents (70%) completed the assessment survey (Table 1). Of these residents, 65% reported that CAS improved their pedicle screw placement accuracy, 60% found CAS to be a helpful educational tool, and 60% believed that CAS was a safer technique than free-hand placement. However, 65% of the residents indicated that they still preferred using the free-hand technique in an educational surgical simulation setting. A second survey was then sent to determine why residents preferred a technique over another after viewing the screw placement results. All residents who preferred CAS as an educational tool responded that visual queue during the trial session helped them to better understand the pedicle screw insertion technique. The residents who preferred the free-hand technique in an educational setting responded with varying reasons: 1 resident (9%) stated that the cost of CAS does not justify its use in an educational setting, another resident (9%) stated that limited experience with CAS does not justify its use, and all the remaining residents (82%) said that the technical aspects of CAS hinder its use in an educational setting.

Although not the primary objective of this pilot study the accuracy of placed screws were verified using CT scans after the training session. Five screws were placed in the safe zone (Grade A or B) and 19 screws were placed in the unsafe zone (Grade C or D; 4 of the screws were dislodged and classified as a grade D) using the free-hand technique, whereas 15 screws were placed in the safe zone and 9 in the unsafe zone using CAS (Table 2 and Fig. 3).

The level of residency was not associated with screw placement accuracy (Table 3). Although no difference in screw placement accuracy was observed in cadavers with mild to moderate spine deformity (Cobb angles of 5º and 15º), a greater number of screws were placed in the unsafe zone using the free-hand technique than CAS (\( p = 0.030, \))

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**Table 1. Results of pedicle screw placement accuracy by resident level and technique**

<table>
<thead>
<tr>
<th>Resident year</th>
<th>Free-hand</th>
<th>CAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade A A</td>
<td>Grade B</td>
</tr>
<tr>
<td>PGY1</td>
<td>0 0 0 3</td>
<td>1 1 0 1</td>
</tr>
<tr>
<td>PGY2</td>
<td>1 1 0 5</td>
<td>3 1 1 2</td>
</tr>
<tr>
<td>PGY3</td>
<td>1 0 1 6</td>
<td>2 3 1 2</td>
</tr>
<tr>
<td>PGY4</td>
<td>2 0 0 4</td>
<td>4 0 1 1</td>
</tr>
<tr>
<td>Total</td>
<td>4 1 1 18</td>
<td>10 5 3 6</td>
</tr>
</tbody>
</table>

CAS = computed-assisted surgery; PGY = postgraduate year.

*Grade A: screw completely in pedicle; grade B: screw < 2 mm outside of pedicle; grade C: screw 2–4 mm outside of pedicle; grade D: screw > 4 mm outside of pedicle.
Table 4) when severe spine deformity was present (Cobb angle of 67°). However, it is worth noting that the majority of the deformity in the cadaver with greatest Cobb angle was in the thoracic region, and no statistical difference between the free-hand and CAS techniques was noted for thoracic screws (Table 5). We observed a difference in screw placement accuracy with regards to the spine region instrumented. In the lumbar spine, only 1 screw was placed in the safe zone and 6 screws were placed in the unsafe zone using the free-hand technique, whereas 9 screws were placed in the safe zone and 1 screw in the unsafe zone using CAS (p = 0.004; Table 5).

**Discussion**

This study aimed to investigate the perception of CAS as an educational tool for the training of orthopedic surgery residents and to verify its effect on pedicle screw placement accuracy among residents in a single educational trial.

The usefulness of CAS as a training tool was confirmed by the residents’ feedback, as the majority reported that CAS allowed for safer screw placement and was a useful tool to learn the standard free-hand technique. However, when residents were asked about their preferred technique in an educational setting, the majority (65%) responded that they preferred the free-hand technique. Among those who preferred the free-hand technique, the majority (82%) stated that the technical complexity of CAS was the main reason for their preference. The residents identified the added visual queue during pedicle screw insertion as an advantage of CAS, but the complex technical aspects seemed to have a negative effect on residents’ perception of this technique.

Interestingly, our findings suggest that CAS helped residents achieve a better screw placement accuracy than the standard free-hand technique, regardless of their level of training or experience. We found that CAS seemed to provide additional guidance for more complex cases, as we observed better screw placement accuracy in the cadaver with severe scoliosis (Cobb angle 67°). Overall, a greater number of screws were placed in the safe zone when residents used the CAS technique. However, this finding was significant only for lumbar screws, and it is important to stress that the study was limited to only 1 trial.

The use of technology, such as robotics, simulations and CAS, for the training of residents is not new.16,17 In fact Haluck and colleagues16 have shown that the use of virtual reality or CAS for the training of residents can have many advantages. Computer simulation is very well documented and has been used successfully in the military and in the aviation field. Its use and interest as an educational tool in the medical field is rapidly growing;16–20 some universities even have dedicated departments for the virtual training of future medical practitioners. Accordingly, the number of orthopedic surgeons using navigation techniques is also increasing. Although CAS has been found to improve surgery outcomes in patients undergoing total knee21–23 or hip24 replacements and to facilitate pedicle screw placement,4,6–8 we are not aware of any study that evaluated the perception and effectiveness of CAS for the training of future orthopedic surgeons.

We believe that learning how to place a safer screw early in training will allow residents to acquire the right technical abilities in a faster time frame. That is, learning the free-hand technique with anatomic landmark is reinforced during training only if real-time feedback of the screw trajectory can be verified by the resident. Instead of just basing their trajectory on anatomic landmarks, CAS allowed residents to see the screw trajectory in real time on the screen and make appropriate adjustments in order to achieve proper screw placement. This real-time feedback may explain why pedicle screw placement accuracy was improved when the residents used CAS as opposed to the free-hand technique in this trial study. Nevertheless, the CAS technique in itself needs to be mastered and taught. Our trial involved an open exposure of the thoracolumbar spine, allowing residents to get both imaging and anatomic feedback during pedicle screw insertion. This can partly explain the improved accuracy of CAS. However, the technical challenges of using CAS were highlighted in the residents’ responses to the survey and should be weighed against its proposed benefit.

It is worth noting that the navigation system used in this study was a 2D fluoroscopy-based system, which may no longer be the norm in spine navigation. Other systems exist and include robotics and 3D navigation systems based on CT scans and even MRI. Moreover, some systems use advanced technology and allow for 3D image guidance. Although the literature has shown that CAS helps improve pedicle screw placement accuracy,25 different navigation systems27 may perform better than others with regards to pedicle screw placement.

<table>
<thead>
<tr>
<th>Resident year; technique</th>
<th>Safe zone</th>
<th>Unsafe zone</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGY1</td>
<td>0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-hand</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>CAS</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>PGY2</td>
<td>0.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-hand</td>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>CAS</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PGY3</td>
<td>0.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-hand</td>
<td>1</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>CAS</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PGY4</td>
<td>0.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-hand</td>
<td>2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>CAS</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

CAS = computer-assisted surgery; PGY = postgraduate year.

*Safe zone refers to grade A or B screw placement, and unsafe zone refers to grade C or D screw placement.
placement accuracy.\textsuperscript{26,27} For instance, CAS systems based on CT scan seem to produce better results than 2D fluoroscopy-based systems. Our results suggest that a CAS system based on 2D fluoroscopy was well perceived by residents as a safe technique, but was limited owing to technical challenges. The results also demonstrated improved pedicle screw accuracy for residents using CAS in a single setting.

\textbf{Limitations}

Other navigation systems can prove to be just as beneficial as the 2D fluoroscopy-based system that we used and may increase accuracy even further. In addition, a major limitation of our study was that each resident placed only 2 screws owing to limited access to cadavers. Although the

\textbf{Fig. 3.} Computed tomography scan example of screw placement accuracy for each grade.
overall performance of residents was noted, this was only a single education simulation, and further studies with larger samples are required to confirm our findings in a more statistically significant manner (i.e., improve β and α error, which were lacking in our study). The technical challenges of CAS may also have been exaggerated since the residents at our institution are not exposed to CAS in a clinical setting; that is, most residents were using CAS for the first time in this trial study.

To the best of our knowledge, this is the first study to investigate residents’ perceptions of CAS and verify the accuracy of the standard free-hand technique compared with CAS for pedicle screw placement in a single trial among orthopedic surgery residents. Our results showed that residents perceived CAS as safe, but also difficult because of the technical challenges associated with its use. In addition, the accuracy of resident pedicle screw placement seemed to improve with CAS. However, our study was limited by a small sample size; although a group of 24 orthopedic residents from a single program is relatively large, we were limited by the number of cadavers available. Consequently, we had to limit the number of screws placed by each resident to only 2. This limitation affects the precision of our results and the statistical power in this preliminary study. Larger studies are warranted to determine whether the results obtained in our trial are reproducible. Studies examining the free-hand technique before and after CAS training can also give a better idea of the effect of CAS in an educational setting.

**Conclusion**

This pilot study investigated orthopedic surgery residents’ perceptions of CAS and showed that CAS was perceived as safe, but technically challenging. Therefore, CAS may need to be more user friendly and less technically challenging in order to improve residents’ perceptions of its use. In future work, a prospective study using the same cohort of residents would be helpful to assess the validity over time and to better evaluate the use of CAS in the training of orthopedic surgery residents.

| Table 3. Screw placement accuracy based on spine deformity and technique* |
|-----------------------------|----------------|-------------|
| Cobb angle; technique       | Safe zone     | Unsafe zone | p value |
| 5°                         | 2             | 5           | 0.10    |
| Free-hand                  | 6             | 1           |         |
| 25°                        | > 0.99        |             |         |
| Free-hand                  | 3             | 6           |         |
| CAS                        | 4             | 5           |         |
| 67°                        | 0             | 8           | 0.030   |
| Free-hand                  | 5             | 3           |         |

CAS = computer-assisted surgery.
*Safe zone refers to grade A or B screw placement, and unsafe zone refers to grade C or D screw placement.

| Table 4. Screws placement accuracy based on spine region (thoracic v. lumbar) and technique* |
|-----------------------------------|----------------|-------------|
| Spine region; technique           | Safe zone     | Unsafe zone | p value |
| Lumbar                            | 1             | 6           | 0.004   |
| Free-hand                         | 9             | 1           |         |
| Thoracic                          | 4             | 13          | 0.44    |
| Free-hand                         | 6             | 8           |         |
| CAS                               |              |             |         |

CAS = computer-assisted surgery.
*Safe zone refers to grade A or B screw placement, and unsafe zone refers to grade C or D screw placement.

<table>
<thead>
<tr>
<th>Table 5. Self-reported survey results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey question</td>
</tr>
<tr>
<td>Navigation helped improve my pedicle screw placement accuracy</td>
</tr>
<tr>
<td>Navigation help me learn the standard free-hand technique</td>
</tr>
<tr>
<td>Navigation was a safer technique</td>
</tr>
<tr>
<td>Free-hand was a safer technique</td>
</tr>
<tr>
<td>Navigation tools were easy to use</td>
</tr>
<tr>
<td>Free-hand was the more accurate technique</td>
</tr>
<tr>
<td>Navigation was your preferred technique in an educational surgical simulation setting</td>
</tr>
<tr>
<td>Free-hand was your preferred technique in an educational surgical simulation setting</td>
</tr>
<tr>
<td>Navigation would be your preferred technique during your residency training</td>
</tr>
<tr>
<td>You will consider using navigation in your future practice as an orthopedic surgeon</td>
</tr>
</tbody>
</table>
Affiliations: From the McGill University Health Centre, Division of Orthopaedics Surgery, Montreal, QC (Aoude, Alhamzah, Fortin, Jarzem, Ouellet, Weber); the McGill Spinal and Spine Centre, McGill University, Montreal, QC (Fortin, Jarzem, Ouellet, Weber); and the Department of Surgery, McGill University, Montreal, Canada (Jarzem, Ouellet, Weber).

Competing interests: None declared.

Contributors: A. Aoude, P. Jarzem, J. Ouellet and M. Weber designed the study. A. Aoude, H. Alhamzah and M. Fortin acquired and analyzed the data, which P. Jarzem, J. Ouellet and M. Weber also analyzed. All authors wrote and reviewed the article and approved the final version for publication.

References

Higher-risk mitral valve operations after previous sternotomy: endoscopic, minimally invasive approach improves patient outcomes

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Background: Reoperative mitral valve (MV) surgery is associated with significant morbidity and mortality; however, endoscopic minimally invasive surgical techniques may preserve the surgical benefits of conventional mitral operations while potentially reducing perioperative risk and length of stay (LOS) in hospital.

Methods: We compared the outcomes of consecutive patients who underwent reoperative MV surgery between 2000 and 2014 using a minimally invasive endoscopic approach (MINI) with those of patients who underwent a conventional sternotomy (STERN). The primary outcome was in-hospital/30-day mortality. Secondary outcomes included blood product transfusion, LOS in hospital and in the intensive care unit (ICU), and postoperative complications.

Results: We included 132 patients in our study: 40 (mean age 68 ± 14 yr, 70% men) underwent MINI and 92 (62 ± 13 yr, 40% men) underwent STERN. The MINI group had significantly more comorbidities than the STERN group. While there were no significant differences in complications, all point estimates suggested lower mortality and morbidity in the MINI than the STERN group (in-hospital/30-day mortality 5% v. 11%, \(p = 0.35\); composite any of 10 complications 28% v. 41%, \(p = 0.13\)). Individual complication rates were similar between the MINI and STERN groups, except for intra-aortic balloon pump requirement (IABP; 0% v. 12%, \(p = 0.034\)). MINI significantly reduced the need for any blood transfusion (68% v. 84%, \(p = 0.036\)) or packed red blood cells (63% v. 79%, \(p = 0.042\)), fresh frozen plasma (35% v. 59%, \(p = 0.012\)) and platelets (20% v. 40%, \(p = 0.024\)). It also significantly reduced median hospital LOS (8 v. 12 d, \(p = 0.014\)). An exploratory propensity score analysis similarly demonstrated a significantly reduced need for IABP (\(p < 0.001\)) and a shorter mean LOS in the ICU (\(p = 0.046\)) and in hospital (\(p = 0.047\)) in the MINI group.

Conclusion: A MINI approach for reoperative MV surgery reduces blood product utilization and hospital LOS. Possible clinically relevant differences in perioperative complications require assessment in randomized clinical trials.
Recherche

MINI (mortalité intrahospitalière ou dans les 30 premiers jours : 5 % c. 11 %, p = 0.35; mortalité combinée à la présence d’au moins une complication parmi 10 possibles : 28 % c. 41 %, p = 0.13). Les taux de complications individuelles étaient semblables chez les patients des 2 groupes, sauf pour l’exigence de ballon de contrepulsion intra-aortique (BCIA; 0 % c. 12 %, p = 0.034). L’approche MINI a réduit significativement le taux de transfusion de sang (68 % c. 84 %, p = 0.036) ou de concentrés de globules rouges (63 % c. 79 %, p = 0.042), de plasma frais congelé (35 % c. 59 %, p = 0.012) et de plaquettes (20 % c. 40 %, p = 0.024), en plus de diminuer significativement la durée médiane d’hospitalisation (8 jours c. 12 jours, p = 0.014). En outre, une analyse exploratoire du score de propension a révélé une réduction significative du BCIA (p < 0.001) ainsi qu’une durée moyenne de séjour à l’USI (p = 0.046) et à l’hôpital (p = 0.047) plus courte dans le groupe MINI.

Conclusion : Le recours à l’approche endoscopique à effraction minimale pour les réopérations de la VM diminuerait le recours aux produits sanguins et la durée d’hospitalisation. En ce qui a trait aux complications périopératoires, il faudra procéder à des essais cliniques aléatoires pour évaluer les différences possiblement pertinentes sur le plan clinique.

Methods

We reviewed the cases of consecutive adult patients who underwent reoperative MV repair or replacement at our institution between September 2000 and August 2014. Patients underwent MV surgery with either a MINI approach performed by 2 surgeons (M.W.C., B.K.) or conventional sternotomy (STERN) performed by 9 different surgeons, including those who performed MINI. We included patients of all urgency statuses in the present investigation; however, those undergoing concomitant coronary artery bypass grafting (CABG), aortic valve surgery and ascending aortic surgery were excluded, as these procedures must be performed only via midline sternotomy. All patients had previously undergone at least 1 open cardiac surgery via sternotomy. The protocol for this investigation was approved by the Health Sciences Research Ethics Board at Western University, which waived the requirement for individual patient consent.

Minimally invasive operative technique

Patients in the MINI group were operated in a 20° left lateral decubitus position with lung isolation. Bicaval venous cannulation was achieved via a 15- or 17-Fr percutaneous superior vena cava (SVC) cannulae inserted through the right internal jugular vein (Fig. 1A) and a 21- or 25-Fr multiport venous drainage catheter placed via the common femoral vein (Fig. 1B). Arterial cannulation was achieved with a 19- or 21-Fr arterial cannulae (2002–2009) or an 8 mm Dacron sidegraft (2009–2015) via either the common femoral artery or the right axillary artery, depending on individual patient risk factors for atheroembolism (atherosclerosis, age > 75 yr, previous stroke). A right anterolateral mini-thoracotomy incision measuring 3–4 cm (Fig. 1C) and a 5 mm endoscope were used for surgical exposure. Hypothermic, ventricular fibrillatory arrest was used for myocardial preservation and was achieved by central cooling to

R eoperative mitral valve (MV) surgery can be technically challenging and is associated with increased risks of mortality and morbidity compared with de novo intervention.1–3 Cardiac injury on re-entry can be hazardous, particularly with patent coronary artery bypass grafts, and postoperative low cardiac output syndrome occurs more commonly as a result of prolonged ischemic time and increased technical complexity.1 Importantly, with a sternotomy approach, adequate operative exposure of the MV can be challenging secondary to dense adhesions — particularly in patients with previous aortic valve and/or aortic root surgery.4–6 Most patients requiring reoperative mitral surgery are older and have multiple medical comorbidities that increase their overall perioperative risk. Recently, many of these higher-risk patients have been offered or treated with novel transcatheter mitral techniques, which may be associated with inferior efficacy and/or aortic root surgery.4–6 Most patients requiring reoperative mitral surgery are older and have multiple medical comorbidities that increase their overall perioperative risk. Importantly, with a sternotomy approach, adequate operative exposure of the MV can be challenging secondary to dense adhesions — particularly in patients with previous aortic valve and/or aortic root surgery.4–6 Most patients requiring reoperative mitral surgery are older and have multiple medical comorbidities that increase their overall perioperative risk. Recently, many of these higher-risk patients have been offered or treated with novel transcatheter mitral techniques, which may be associated with inferior efficacy and have unknown durability. A minimally invasive, endoscopic right mini-thoracotomy (MINI) approach for reoperative MV surgery may reduce risk while preserving late outcomes of a conventional surgical operation. It can reduce the extent of adhesiolysis while facilitating excellent exposure of the MV. Several centres worldwide have demonstrated the feasibility and safety of this minimally invasive technique,7–10 but its adoption in Canada has been slow.11 Critics remain concerned about risks of iatrogenic aortic dissection and stroke12 in minimally invasive surgery compared with conventional surgery.

We therefore sought to review our experience with the minimally invasive endoscopic, right MINI approach compared with conventional sternotomy (STERN) in order to better delineate the benefits and limitations of both techniques with respect to reoperative MV surgery in a higher-risk patient population. We used a retrospective cohort study design and hypothesized that, compared with sternotomy, a minimally invasive approach would demonstrate improved outcomes despite patients being older and sicker.
RESEARCH

28–30°C and using a fibrillator box with pacemaker wires. The perfusion pressure was maintained at 80–100 mm Hg during ventricular fibrillation, and aortic root venting was used selectively depending on ascending aortic calcification. Special long-shafted instruments were used to perform the MV repair or replacement using standard techniques, similar to those in the STERN group (Fig. 1D).

**Conventional sternotomy operative techniques**

Patients in the STERN group underwent a standard midline resternotomy for surgical exposure with central arterial and venous cannulation. All operations were performed with an aortic cross clamp, and myocardial protection consisted of a combination of antegrade and retrograde blood cardioplegia. Conventional instruments were used, and the MV repair or replacement was performed using standard techniques similar to those in the MINI group.

**Statistical analysis**

We compared preoperative characteristics and postoperative outcomes of patients in the 2 groups using the \( \chi^2 \) test (for categorical variables) and either the \( t \) test (if visual inspection of a histogram indicated an approximately normal distribution) or the Wilcoxon rank-sum test (if visual inspection of a histogram indicated a non-normal distribution) for continuous variables. Univariable logistic regression was used to compute unadjusted odds ratios (ORs) for dichotomous outcomes. Length of stay data in patients who survived their hospitalization are presented as medians and were tested for differences using Cox regression. We used Casewise deletion for missing data.

As an exploratory analysis, we controlled for confounding by performing adjusted analyses using inverse probability weighting (IPW) based on the propensity score of receiving either the MINI approach or the STERN approach. To calculate the propensity score, we constructed a logistic regression model based on covariates deemed from clinical experience or from previous literature to likely be predictive of the surgical approach used or the outcomes of interest. This included the following baseline variables: age, sex, body mass index, diabetes, previous stroke or transient ischemic attack (TIA), chronic obstructive pulmonary disease, left ventricular grade, congestive heart failure, coronary artery disease and atrial fibrillation. This model had reasonable reliability (Hosmer–Lemeshow goodness of fit [10 groups], \( p = 0.08 \)) and had good discrimination (c statistic = 0.82). We then performed IPW-adjusted analysis of our outcomes using the “teffects ipw” package in Stata software version 14.

**Fig. 1.** (A) Insertion of percutaneous superior vena cava line. (B) Venous femoral cannulation. (C) Right mini-thoracotomy approach for reoperative mitral valve surgery with right axillary artery cannulation. (D) Intraoperative photograph of an endoscopic mitral valve repair demonstrating no intraoperative mitral regurgitation.
(StataCorp LP) and using the average treatment effect. We considered results to be significant at $p < 0.05$, 2-tailed.

**RESULTS**

*Patients and operative details*

During the study period, 132 consecutive adult patients underwent reoperative MV repair ($n = 16$) or replacement ($n = 116$) at our institution; 40 patients received a MINI approach and 92 received conventional sternotomy. All patients had previously undergone at least 1 open cardiac surgery via sternotomy (Table 1); 106 patients had previously undergone only 1 prior cardiac surgery, 20 patients had 2 prior interventions, 2 patients had 3 prior interventions, and 3 patients had 4 previous cardiac operations. One individual in the STERN group had 5 previous cardiac surgeries. Figure 2 shows the wounds from MINI compared with previous sternotomy wounds.

Preoperative patient characteristics are outlined in Table 2. Mean patient age was significantly older in the MINI group, and there were more female patients in the STERN group. The MINI group also had more patients with moderate to severe left ventricular dysfunction, peripheral vascular disease, chronic obstructive pulmonary disease and coronary artery disease. The median number of prior surgical interventions and urgency status was similar in both groups. Despite significant differences in patient profiles, the calculated Society of Thoracic Surgery risk scores were similarly elevated. There was no statistically significant difference in proportion of patients who underwent MV repair versus replacement between the 2 groups. Additionally, there were similar proportions of patients who underwent concomitant procedures, with approximately one-third of both groups undergoing a concomitant tricuspid valve repair. There was a trend toward longer cardiopulmonary bypass times in the MINI group (on average 21 min longer), and the MINI group had longer cross clamp/ventricular fibrillation times (on average 18 min longer; Table 3).

**Mortality and morbidity**

Unadjusted patient outcomes are presented in Table 4. In-hospital/30-day mortality was statistically similar in both groups, although it was more than 2-fold greater in the STERN group than the MINI group. Two patients in the MINI group died; 1 patient experienced a cardiac arrest due to an intraoperative type A dissection originating from the aortic root vent site, and 1 patient died from complications of heparin-induced thrombocytopenia. The causes of death in the STERN group were cardiac failure ($n = 5$), multisystem organ failure ($n = 1$), septic shock ($n = 2$), cardiogenic shock ($n = 1$) and AV groove disruption ($n = 1$). Significantly more patients in the

<table>
<thead>
<tr>
<th>Table 1. Previous operations</th>
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<tbody>
<tr>
<td>Group; no. (%)*</td>
</tr>
<tr>
<td>Isolated MVR/repair</td>
</tr>
<tr>
<td>MVR/repair ± other valve ± CABG</td>
</tr>
<tr>
<td>CABG</td>
</tr>
<tr>
<td>AVR/repair ± aortic ± CABG</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

AVR = aortic valve replacement; CABG = coronary artery bypass grafting; MINI = mini-thoracotomy; MVR = mitral valve replacement; STERN = conventional sternotomy.

*Data are rounded to the nearest integer. Values do not add to 100% as many patients had more than 1 prior cardiac surgery.
STERN group required postoperative intra-aortic balloon pump (IABP) use. The rate of other individual major complications was also similar, with the most common complication being prolonged mechanical ventilation (> 48 h). There were no differences in stroke and other neurologic complications between the 2 groups. A composite outcome of any of 10 complications was also considerably less frequent in the MINI group, though this difference was not statistically significant. No patients in the MINI group required conversion to sternotomy. An exploratory propensity score analysis (Table 5) demonstrated a significant reduction in risk difference with respect to postoperative IABP requirement in the MINI group. There was also a significant reduction in risk difference for both reoperation for bleeding and renal failure requiring dialysis in the MINI group.

**Length of stay**

Length of stay (LOS) in the intensive care unit (ICU) was similar in both groups (MINI: mean 2, interquartile range [IQR] 1–4; STERN: mean 2, IQR 1–6; hazard ratio [HR] for discharge from ICU 1.3, 95% confidence interval [CI] 0.89–1.9, \( p = 0.18 \)); however the overall hospital LOS was significantly shorter in the MINI group than the STERN group (median 8, IQR 6–13 v. median 12, IQR 8–20; HR for discharge from hospital 1.6, 95% CI 1.1–2.4, \( p = 0.014 \); Table 4). There was also a strong trend toward a significant reduction in the proportion of patients requiring any prolonged postoperative hospitalization in the MINI compered with the STERN group (LOS > 10 d; 15 [38%] v. 51 [55%], \( p = 0.06 \)). These trends were similar in the propensity score analysis, which demonstrated a significant reduction in the risk difference in both the

<table>
<thead>
<tr>
<th>Table 2. Preoperative patient characteristics</th>
</tr>
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<tbody>
<tr>
<td>Characteristic</td>
</tr>
<tr>
<td>Male sex</td>
</tr>
<tr>
<td>Age, yr</td>
</tr>
<tr>
<td>BMI</td>
</tr>
<tr>
<td>NYHA</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
<tr>
<td>IV</td>
</tr>
<tr>
<td>STS score</td>
</tr>
<tr>
<td>LV grade 3/4</td>
</tr>
<tr>
<td>No. previous operations</td>
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</table>

**Table 3. Operative characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>MINI (n = 40)</th>
<th>STERN (n = 92)</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MV Repair</td>
<td>8 (20)</td>
<td>8 (9)</td>
<td>0.07</td>
</tr>
<tr>
<td>MVR</td>
<td>32 (80)</td>
<td>84 (91)</td>
<td>0.07</td>
</tr>
<tr>
<td>Concomitant procedure</td>
<td>15 (38)</td>
<td>40 (44)</td>
<td>0.62</td>
</tr>
<tr>
<td>TV</td>
<td>12 (30)</td>
<td>32 (35)</td>
<td>0.59</td>
</tr>
<tr>
<td>ASD</td>
<td>2 (5)</td>
<td>4 (4)</td>
<td>0.87</td>
</tr>
<tr>
<td>Ablation</td>
<td>2 (5)</td>
<td>4 (4)</td>
<td>0.87</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>3 (3)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Table 4. Postoperative outcomes and complications**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>MINI (n = 40)</th>
<th>STERN (n = 92)</th>
<th>( p ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-hospital/30-d mortality</td>
<td>2 (5)</td>
<td>10 (11)</td>
<td>0.35</td>
</tr>
<tr>
<td>Reoperation for bleeding</td>
<td>1 (3)</td>
<td>6 (7)</td>
<td>0.68</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>7 (18)</td>
<td>19 (21)</td>
<td>0.68</td>
</tr>
<tr>
<td>Postoperative IABP</td>
<td>0</td>
<td>11 (12)</td>
<td>0.034</td>
</tr>
<tr>
<td>Neurological complications</td>
<td>3 (8)</td>
<td>6 (7)</td>
<td>&gt; 0.99</td>
</tr>
<tr>
<td>Stroke</td>
<td>2 (5)</td>
<td>2 (2)</td>
<td>0.58</td>
</tr>
<tr>
<td>Arrest or serious arrhythmia</td>
<td>1 (3)</td>
<td>12 (13)</td>
<td>0.11</td>
</tr>
<tr>
<td>Renal failure requiring dialysis</td>
<td>0</td>
<td>6 (7)</td>
<td>0.18</td>
</tr>
<tr>
<td>Septicemia</td>
<td>0</td>
<td>2 (2)</td>
<td>&gt; 0.99</td>
</tr>
<tr>
<td>Wound infection</td>
<td>0</td>
<td>3 (3)</td>
<td>0.55</td>
</tr>
<tr>
<td>Any of 10 major complications</td>
<td>11 (28)</td>
<td>38 (41)</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**LOS**

| ICU | 2 [1–4] | 2 [1–6] | 0.40 |
| > 4 d in ICU | 8 (20) | 27 (29) | 0.26 |
| Hospital LOS | 8 [6–13] | 12 [8–20] | 0.021 |
| > 10 d in hospital | 15 [38] | 51 (55) | 0.06 |

**IABP** = intra-aortic balloon pump; **ICU** = intensive care unit; **IQR** = interquartile range; **LOS** = length of stay; **MINI** = mini-thoracotomy; **STERN** = conventional sternotomy. *Data are rounded to the nearest integer.
mean ICU (–3.3, 95% CI –6.6 to –0.06, p = 0.046) and hospital LOS (–4.3, 95% CI –8.6 to –0.06, p = 0.047) in the MINI group.

Blood product usage

Patients in the MINI group had a lower proportion of patients requiring any blood transfusion than the STERN group (68% v. 84%, p = 0.036), which was consistent when broken down by individual blood product (packed red blood cells [pRBC]: 63% v. 79%, p = 0.042; fresh frozen plasma [FFP]: 35% v. 59%, p = 0.012; platelets: 20% v. 40%, p = 0.024). When transfused, patients in the MINI group also received fewer units of FFP than those in the STERN group (median 4, IQR 2–6 v. median 6, IQR 4–11, p = 0.016) and strongly trended toward reduced platelet requirements (median 5, IQR 5–5 v. median 10, IQR 5–15, p = 0.06; Fig. 3).

Survival and follow-up

Survival in the MINI group was 97% at 1 and 2 years, and 58% at 5 years, whereas survival in the STERN group was 93% at 1 year, 92% at 2 years, and 84% at 5 and 10 years. Log-rank analysis revealed similar survival in both groups (p = 0.55). Clinical follow-up revealed that 6 (16%) patients in the MINI group continued to experience New York Heart Association functional III/IV symptoms at a median follow-up of 10 (IQR 4–22) months, which was similar to the 10 (14%) patients in the STERN group at a median follow-up of 30 (IQR 4–75) months (p = 0.71). Freedom from recurrent moderate mitral regurgitation was 94% in the MINI group and 90% in the STERN group (p = 0.71) at a median echocardiographic follow-up of 10 (IQR 2–40) months.

Discussion

Minimally invasive approaches for both primary and re-operative MV surgery are becoming increasingly accepted, as many groups continue to demonstrate low rates of complications and excellent postoperative outcomes.7–9,14,15 The results of our present investigation provide further evidence to support the safety and efficacy of the MINI approach for redo MV surgery and should serve to assure patients that these minimally invasive options are available in Canada and are being performed with outcomes comparable to those of larger published series.

Seeburger and colleagues7 published their experience with 181 patients undergoing redo sternotomy. Mihos and colleagues16 demonstrated that the less invasive approach for redo MV surgery and should serve to assure patients that these minimally invasive options are available in Canada and are being performed with outcomes comparable to those of larger published series. They confirmed the safety of the MINI approach; however, they found no difference in the overall operative mortality in patients undergoing MINI compared with those undergoing sternotomy (6% in both groups, p = 0.98). Similar to our findings, Bolotin and colleagues15 demonstrated that the less invasive approach resulted in significantly reduced postoperative intubation time (p = 0.008), reduced transfusion requirements (p = 0.001) and reduced hospital LOS (p = 0.001) when compared with redo sternotomy. Mihos and colleagues15 reported a similarly low 30-day mortality of 5% in their series of 107 patients. Neurological complications were also infrequent, with only 1 patient experiencing a stroke, and they reported 1 patient experiencing an acute type A aortic dissection.
intubation time and hospital LOS; however, unlike in our present investigation, there were no differences in blood product requirements between the 2 groups. We are satisfied that our present results are comparable to those of these other series. Although our results did not demonstrate a statistically significant difference between groups in early mortality or complication rates, we feel that this is likely reflective of inadequate power and that, with more patients being treated, the evidence will strongly favour the MINI approach.

We have made several technique changes to our MINI approach over the years. Early in our experience, we had 1 patient experience an acute type A aortic dissection, originating from the aortic root vent site (not from retrograde femoral perfusion). Since then, we no longer use an aortic root vent in patients with any concerning ascending aortic plaque. We continuously flood the operative field with CO₂ and rely on de-airing with a left ventricular vent placed across the mitral repair/prosthesis, until any remaining intracardiac air has been completely evacuated. Furthermore, our perfusion strategy has also evolved, and we now prefer to use an 8 mm Dacron side graft to the axillary artery for the delivery of antegrade arterial perfusion for the reoperative MINI approach. This technique allows us to avoid manipulation of often diseased femoral vessels and instead use the axillary artery, which may reduce the risk of stroke. Since implementing these changes, we have not experienced any dissections or strokes in our minimally invasive group, despite the large number of patients with peripheral vascular disease.

The reoperative MINI approach requires specialized training and instrumentation, a dedicated team and substantial surgeon experience to achieve good results in these challenging patients. Currentlly, there is a growing trend to refer or treat these high-risk reoperative MV patients with novel transcatheter MV replacement or repair, frequently citing prohibitive operative risk. While these novel transcatheter techniques appear promising in the initial reports, they may not have the long-term durability of conventional MV surgery. We believe that reoperative MINI MV surgery is a good alternative and should be considered before more novel techniques because of proven late outcomes. More than one-third of the patients in the MINI group were deemed inoperable by another surgeon and were referred to our centre specifically for redo MINI MV surgery. We demonstrated that the MINI approach is feasible, safe and effective and may reduce the frequency of perioperative complications and the need for blood product transfusions, while preserving the late outcomes of surgical repair.

**Limitations**

Our investigation has a number of limitations, including the modest sample sizes and somewhat heterogenous patient characteristics. We attempted to adjust for the imbalances in prognostic factors observed with an exploratory propensity score analysis. However, residual confounding is still likely owing to the small sample size and event rates — this is evident in the wide CIs observed for several of the propensity
score-adjusted outcomes. The generalizability of our outcomes is limited by the single-centre data, as our surgical group had considerable pre-existing experience in minimally invasive techniques. We believe this study provides important comparative data that are missing in the current literature, as most investigations to date are limited to only the minimally invasive outcomes.

**CONCLUSION**

Our study has demonstrated that an endoscopic, right mini-thoractomy approach to reoperative MV surgery is safe and effective and provides superior postoperative outcomes than conventional sternotomy. Specifically, the minimally invasive approach likely results in fewer postoperative complications and significantly reduces both blood product requirements and hospital LOS.

**Affiliations:** From the Division of Cardiac Surgery, Department of Surgery, Western University, Lawson Health Research Institute, London, Ont., (Losenno, Valdis, Fox, Kiaii, Chu); and the Department of Anesthesia & Perioperative Medicine and Epidemiology & Biostatistics, Western University, London, Ont., (Jones).

**Competing interests:** B. Kiaii is a consultant and proctor for and has received speaker fees from Medtronic, Symetis, Johnson & Johnson, and LivaNova. M. Chu has received speaker fees from Medtronic, Edwards Lifesciences, LivaNova and Symetis. No other competing interests declared.

**Contributors:** P. Jones, S. Fox, B. Kiaii and M. Chu designed the study. K. Losenno, S. Fox and M. Chu acquired the data, which K. Losenno, P. Jones, M. Valdis and M. Chu analyzed. K. Losenno, P. Jones and M. Chu wrote the article, which all authors reviewed and approved for publication.

**References**

The development and validation of a multivariable model to predict whether patients referred for total knee replacement are suitable surgical candidates at the time of initial consultation

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J. Robert Giffin, MD, MBA

Background: In previous studies, 50%–70% of patients referred to orthopedic surgeons for total knee replacement (TKR) were not surgical candidates at the time of initial assessment. The purpose of our study was to identify and cross-validate patient self-reported predictors of suitability for TKR and to determine the clinical utility of a predictive model to guide the timing and appropriateness of referral to a surgeon.

Methods: We assessed pre-consultation patient data as well as the surgeon’s findings and post-consultation recommendations. We used multivariate logistic regression to detect self-reported items that could identify suitable surgical candidates.

Results: Patients’ willingness to undergo surgery, higher rating of pain, greater physical function, previous intra-articular injections and patient age were the factors predictive of patients being offered and electing to undergo TKR.

Conclusion: The application of the model developed in our study would effectively reduce the proportion of nonsurgical referrals by 25%, while identifying the vast majority of surgical candidates (> 90%). Using patient-reported information, we can correctly predict the outcome of specialist consultation for TKR in 70% of cases. To reduce long waits for first consultation with a surgeon, it may be possible to use these items to educate and guide referring clinicians and patients to understand when specialist consultation is the next step in managing the patient with severe osteoarthritis of the knee.

Contexte : Dans des études précédentes, de 50 % à 70 % des patients dirigés vers des chirurgiens orthopédistes pour une arthroplastie totale du genou (ATG) n’étaient pas des candidats à la chirurgie au moment de l’évaluation initiale. Notre étude visait à recenser et à contrevalider les facteurs prédictifs de l’opportunité d’une ATG fondés sur des renseignements fournis par les patients, ainsi qu’à déterminer l’utilité clinique d’un modèle de prévision qui évaluerait le moment et la pertinence de diriger un patient vers un chirurgien.

Méthodes : Nous avons évalué les données des patients préconsultation ainsi que les conclusions du chirurgien et ses recommandations postconsultation. Nous avons mené une analyse de régression logistique multivariée pour détecter les éléments autodéclarés qui permettraient de reconnaitre les candidats pour la chirurgie.

Résultats : Les facteurs permettant de prédire si un patient se ferait offrir une ATG et choisirait de subir l’intervention étaient la disposition favorable du patient à se faire opérer, une douleur d’intensité élevée, des capacités physiques fonctionnelles supérieures, des antécédents d’injections intra-articulaires et l’âge.

Conclusion : Concrètement, l’application du modèle élaboré durant notre étude réduirait le nombre de patients dirigés vers un chirurgien sans motif valable dans une proportion de 25 %, tout en permettant de reconnaitre la vaste majorité des candidats à la chirurgie (> 90 %). À partir des renseignements fournis par les patients, nous pouvons prédire correctement le résultat d’une consultation avec un spécialiste pour une ATG dans 70 % des cas. Les conclusions de notre étude pourraient servir à réduire les longs délais d’attente pour une première consultation avec un chirurgien en aidant les professionnels de la santé et les patients à déterminer quand il convient de consulter un spécialiste pour la prise en charge d’une gonarthrose grave.
Worldwide estimates indicate that approximately 10%–20% of people older than 60 years have symptomatic osteoarthritis (OA).1 Currently, 4.4 million, or 1 in 8, Canadians are living with OA, and this number is expected to increase to 10.4 million by the year 2040.2 Because of its substantial direct and indirect costs, OA is a growing public health care concern.3,4 The annual economic burden of OA is expected to reach $405 billion by the year 2020 in Canada alone, emphasizing the need to spend health care dollars wisely.2

Total joint replacement (TJR) is an effective intervention for patients with moderate to severe OA in their lower limbs.1 According to the Arthritis Alliance of Canada, TJRs could avert more than 72 000 cases of severe OA over the next 30 years while also improving the symptoms and physical functioning of individuals living with the disease.2 However, provincial and nationwide reports indicate that wait times for Canadians to see an orthopedic surgeon are longer than acceptable.6

Total knee replacement (TKR) accounts for the majority of joint replacement surgeries in Canada,7 therefore targeting a reduction in wait times for TKRs will have the greatest impact in wait time statistics. Despite the growing concern regarding wait times for TKR, current efforts focus on reducing wait times for total joint replacement; there is a limited amount of research that specifically targets improvements in the wait from referral to initial consultation with an orthopedic specialist.8

Interestingly, current evidence suggests that nearly 50%–70% of patients referred to an orthopedic surgeon for TKR are not scheduled for surgery.9,10 In a public health care system, ensuring that patients are seen by the appropriate specialist at the right time is key to ensure efficient allocation of health care resources and timely access to care.

A proposed solution to help mitigate the demand for orthopedic specialist care is to establish central intake and assessment centres (CIACs), where other allied health professionals (physical therapists, nurse practitioners) screen, triage and provide nonoperative care to patients referred for TKR. Although a CIAC may help alleviate excessive wait times for surgical consultations, they may not represent an efficient model of care, given that anecdotal reports are that most patients referred for TKR eventually undergo surgery and that CIACs mandate an additional costly point of care.11 Ensuring the majority of patients referred to orthopedic specialists for TKR are interested in and eligible candidates for surgery could be achieved through simpler, less costly means than CIACs, such as nonoperative management at the discretion of the family physician and appropriate education for family physicians regarding surgical candidacy.

Thus, the purpose of the present study was to identify the reasons patients are classified as nonsurgical candidates after consultation with an orthopedic surgeon, identify and validate patient-reported predictors of being offered and electing to undergo TKR during the initial consultation, and determine the clinical utility of a predictive model to guide the referral to a surgeon for TKR.

**METHODS**

**Study design and setting**

This study took place in a clinic that specializes in joint replacement at University Hospital, London Health Sciences Centre, London, Ont., Canada. The centre performs 1700 TKR surgeries per year, which accounts for approximately 3% of all joint replacement surgeries performed annually in Canada.17 This study used a single-centre prospective cohort design conducted with patients who were attending their first consultation for their knee with 1 of 7 fellowship-trained arthroplasty surgeons. Prior to meeting with the surgeon, patients completed a series of questionnaires. Following the consultation, the attending surgeon completed a form detailing their findings and recommendations for treatment. The study was approved by the Health Sciences Research Ethics Board at Western University.

**Participants**

Patients aged 18–100 years who were referred by their primary health care providers for their first consultation for surgical treatment of knee OA were eligible to participate in this study. Patients were ineligible if they did not speak English; if they were deemed by the orthopedic surgeon to be a complex case; if they were not a new referral; if they had previously undergone a TKR; or if they were unable to complete the questionnaire because of psychiatric, cognitive, visual or physical impairment.

All newly referred patients were identified by the study coordinator before their surgical consultation and were registered into a secure web-based data management system (www.empowerhealthresearch.ca; EmPower Health Research Inc.). Participants were provided a unique username and password that allowed them to login and complete the questionnaires before their appointment. Several studies support the validity of online data collection.13–15 Patients who chose not to complete questions online were provided a paper copy of the questionnaires to complete in the waiting room before meeting with the surgeon.

**Outcome measures**

We developed a patient demographic and OA questionnaire. The selection and content of the initial patient questionnaires was informed by a thorough literature review followed by a meeting of the participating arthroplasty surgeons who discussed (until consensus) the expected strength of association between collected information and likelihood that patients reporting those
characteristics would be scheduled for TKR by the end of the consultation. Because we were interested in identifying items that did not require interference or interpretation by a clinician (in the interest of removing the need for a CIAC), only patient-reported items were included.

Specifically, we included demographic information including age, sex, body mass index (BMI), employment status, presence/absence of bilateral symptoms, previous use of allied health (i.e., physiotherapy, chiropractor, massage therapy), use of intra-articular injections, use of walking aids, and willingness to undergo surgery. Patients indicated their willingness by selecting 1 of 5 response options; a participant was considered “willing” if they selected the response “definitely willing” or “probably willing,” or “unwilling” if they selected the response “unsure,” “probably unwilling,” or “definitely unwilling.”

Patients also completed the Short Form 12-item survey (SF-12)\(^{16}\) and a global rating of knee pain on a numeric scale from 0 to 10, where 0 represents no pain. We also used the Patient Acceptable Symptom State questions (PASS 1 and 2) for OA (in relation to activities of daily living [ADLs], pain and function). The PASS 1 asks, “Taking into account all the activities you have during your daily life, your level of pain, and also your functional impairment, do you consider that your current state is satisfactory?” The PASS 2 asks, “Considering all the different ways in which your disease affects you, if you were to remain in this state for the next few months, would you consider your current state to be satisfactory?”\(^{17}\) The response options were yes/no.

After the orthopedic surgeon performed the usual initial consultation with the participant, the surgeon completed a form detailing their findings and recommendations. The surgeons were blind to participant outcome measures, as only the primary data collector retained access to this information. The form asked the surgeon to indicate whether the participant was an appropriate candidate for TKR. If yes, the surgeon indicated whether the consultation resulted in a booking for TKR; if no, the surgeon was asked to indicate the reason(s) via a standard checklist, which was determined a priori by all participating surgeons.

We constructed a simplified algorithm based on model findings and our recommendations for clinicians.

**Statistical analysis**

Based on the literature and surgeon expertise, we identified 9 items that were most likely to identify surgical candidates: age, BMI, unilateral/bilateral symptoms, willingness to undergo surgery, previous use of allied health, use of injections, use of walking aids, SF-12 Physical Composite Scale (PCS), and global rating of knee pain. We then set out to determine whether we could use patient responses to questionnaire items to identify patients who are scheduled for TKR during their initial consultation (dependent variable).

Our sample size was calculated based on the formula used by Peduzzi and colleagues:\(^{18}\) \(n = 10 \times k \div p\), where \(p\) was the limiting event rate or the proportion of referrals deemed to be nonsurgical candidates (47%)\(^{9}\) and \(k\) was the number of predictors. This yielded a sample size requirement of approximately 200 individuals.

Since our intention was to run both a model development analysis (training sample) and a validation analysis (testing sample) we required approximately 400 individuals randomly divided into 2 equally sized groups. We used an all enter method of multivariate logistic regression analysis where we pared down our model by eliminating any predictors with an \(\alpha > 0.20\) and used the Hosmer–Lemeshow test to confirm the model fit. Model diagnostics were performed following Menard’s method.\(^{19}\)

Next, we performed additional analyses with predictors that assessed similar constructs, such as those measuring pain and function. Specifically, we repeated our analysis by replacing global rating of pain and SF-12 PCS with the PASS 1 and PASS 2 questions, respectively, in both the training and validation models.

Last, we identified a final clinical model encompassing terms that were significant in both the training and test models that considered the results of our additional analyses. We calculated the sensitivity and specificity of this model to correctly identify patients booked for TKR following first consult using a standard cut-off value of 0.5. We then adjusted the cut-off value in increments of 0.5 to determine whether we could improve the sensitivity of our model.

All data analyses were performed using SPSS version 22.0 (SPSS Inc.).

**RESULTS**

**Study population**

Of the patients who consented to participate, demographic characteristics were similar between those who completed all questionnaires and those who did not. Patients who refused consent tended to be older than those who consented (Table 1).

From Apr. 17, 2013, to Feb. 19, 2014, a total of 883 patients were consecutively screened for eligibility. Of these, 63 did not meet eligibility requirements, 40 patients did not attend their appointment, 58 were missed, and 84 refused consent. Of the 638 eligible patients who gave their consent, 406 patients fully completed the study protocol (Fig. 1). Using the American Association for Public Opinion Research (AAPOR) standard,\(^{20}\) our response rate was 72%. Our training and testing samples each comprised 203 patients.

Assumptions of the logistic model were confirmed. Within our training sample, 91 of 203 participants (44.8%) were not scheduled for surgery during the initial consultation with the orthopedic surgeon. Figure 2 describes the
reasons why patients were considered nonoperative, as indicated by their surgeon.

The final training and validation logistic regression models are shown in Table 2. Five variables were identified in the training model as being significant contributors to identifying surgical candidates: age, global rating of pain, SF12 PCS, willingness to undergo surgery, and previous injections. All of these variables were significant in the validation model in addition to BMI, bilateral symptoms and previous use of allied health care. Thus, the original model was validated, as all of the predictors identified as significant in the training model were also significant in the validation model, with odds ratios of similar magnitudes.

We found that willingness to undergo surgery was the strongest predictor of being scheduled for TKR during the initial consultation. In the training sample, patients who were willing to undergo surgery were approximately 4.5 times more likely to be scheduled for TKR (95% confidence interval [CI] 1.64–12.08, \( p = 0.003 \)). This was further confirmed by the validation sample, in which patients who were willing to undergo surgery were approximately 10 times as likely to be scheduled for TKR (95% CI 3.01–31.71, \( p < 0.001 \)).

Several other variables were identified as significant predictors in both the training and validation samples. Specifically, the greater the pain reported by the patient, the more likely they were to be scheduled for TKR (i.e., for every 1 unit increase on the 0–10 global rating of pain numeric rating scale, patients were 20% more likely to be scheduled for TKR). The higher a patient scored on the SF-12 (i.e., better function), the less likely they were to be scheduled for TKR. Patients who had tried injections were 1.5 times more likely to be scheduled for TKR than those who had not tried injections. Finally, age was a significant predictor in both models.
Additional analyses

In the training model, when we removed the global rating of pain variable and replaced it with the PASS 1, patients who answered “yes” (i.e., they felt that their current level of pain and functional impairment was acceptable) were approximately 75% less likely to be scheduled for TKR than those who answered “no.” When we replaced the SF-12 PCS with the PASS 2 question, patients who answered “yes” (i.e., they felt that their current disease state was acceptable) were approximately 50% less likely to be scheduled for TKR than those who answered “no.” Results of these additional analyses revealed that the model fit improved in both the training and validation models when PASS 1 (Table 3) and PASS 2 (Table 4) were substituted into the model, whereas the other terms remained relatively stable.

Final clinical model

In formulating the final clinical model, the PASS 2 is preferable based on the clinical utility of a single question

### Table 2. Training and validation, final models

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Training data set</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.06 (1.02–1.10)</td>
<td>0.001</td>
</tr>
<tr>
<td>Global rating of pain</td>
<td>1.24 (1.06–1.44)</td>
<td>0.006</td>
</tr>
<tr>
<td>SF-12 PCS</td>
<td>0.95 (0.91–0.98)</td>
<td>0.004</td>
</tr>
<tr>
<td>Willingness</td>
<td>4.45 (1.64–12.08)</td>
<td>0.003</td>
</tr>
<tr>
<td>Tried injections</td>
<td>1.73 (0.89–3.36)</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Validation data set</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.02 (0.99–1.06)</td>
<td>0.19</td>
</tr>
<tr>
<td>BMI</td>
<td>1.05 (0.99–1.10)</td>
<td>0.09</td>
</tr>
<tr>
<td>Bilateral/unilateral symptoms</td>
<td>0.57 (0.29–1.11)</td>
<td>0.10</td>
</tr>
<tr>
<td>Global rating of pain</td>
<td>1.23 (1.06–1.42)</td>
<td>0.007</td>
</tr>
<tr>
<td>SF-12 PCS</td>
<td>0.97 (0.94–1.01)</td>
<td>0.15</td>
</tr>
<tr>
<td>Willingness</td>
<td>9.77 (3.02–31.64)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Tried injections</td>
<td>1.60 (0.83–3.12)</td>
<td>0.16</td>
</tr>
<tr>
<td>Allied health</td>
<td>0.45 (0.14–1.46)</td>
<td>0.18</td>
</tr>
</tbody>
</table>

BMI = body mass index; CI = confidence interval; OR = odds ratio; SF-12 PCS = Short-Form 12-item survey Physical Composite Scale.

*–2Logl = 220.123; Hosmer–Lemeshow $\chi^2_{8df} = 9.75$, $p = 0.28$. Final training model following 5 deletions.

†–2Logl = 216.283; Hosmer–Lemeshow $\chi^2_{8df} = 7.45$, $p = 0.49$. Final validation model following 2 deletions.

---

![Fig. 2. Reasons why patients were considered nonoperative, as indicated by their surgeon.](image-url)
versus a 12-item questionnaire. Although the additional analyses evaluated similar constructs with different measures, we cannot compare them directly because they are scaled differently. To avoid collinearity between PASS 1 and PASS 2 statements, it is more suitable to include the global rating of pain in a final predictive model that includes the PASS 2. Thus, our final clinical model includes the following predictor variables: age, willingness to undergo surgery, global rating of pain, PASS 2 and previous injections (Table 5). Cut-off values of 0.5 and 0.35 were used to compute the sensitivity and specificity and overall percentage correct of the final clinical models (training and validation; Table 6). In the training sample, using a cut-off value of 0.5 this model would have correctly screened out 57 of 91 (62%) patients who were not surgical candidates at the time of first consultation, while correctly identifying 87 of 112 (77%) patients scheduled for TKR. Using a cut-off value of 0.35, this model would have correctly screened out 40 of 91 (44%) nonoperative patients, while correctly identifying 104 of 112 (92%) patients scheduled for TKR.

Based on model findings and clinical experience a simplified algorithm for referring physicians is described (Fig. 3).

### Discussion

We found that a large proportion of referrals for TKR (approximately 45%) were not suitable or “ready” candidates for joint replacement at the time of their initial surgical consultation (i.e., the patient was unwilling to

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**Table 3. Additional analysis (PASS 1): training and validation, final models**

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training data set*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.05 (1.02–1.09)</td>
<td>0.004</td>
</tr>
<tr>
<td>PASS 1</td>
<td>0.28 (0.12–0.66)</td>
<td>0.004</td>
</tr>
<tr>
<td>SF-12 PCS</td>
<td>0.95 (0.91–0.98)</td>
<td>0.003</td>
</tr>
<tr>
<td>Willingness</td>
<td>4.60 (1.70–12.50)</td>
<td>0.003</td>
</tr>
<tr>
<td>Tried injections</td>
<td>1.64 (0.84–3.20)</td>
<td>0.15</td>
</tr>
</tbody>
</table>

**Validation data set†**

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.02 (0.99–1.06)</td>
<td>0.20</td>
</tr>
<tr>
<td>BMI</td>
<td>1.06 (1.00–1.11)</td>
<td>0.035</td>
</tr>
<tr>
<td>Bilateral/unilateral symptoms</td>
<td>0.49 (0.25–0.95)</td>
<td>0.034</td>
</tr>
<tr>
<td>PASS 1</td>
<td>0.22 (0.10–0.48)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Willingness</td>
<td>11.51 (3.57–37.07)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Tried injections</td>
<td>1.67 (0.86–3.22)</td>
<td>0.13</td>
</tr>
<tr>
<td>Allied health</td>
<td>0.38 (0.12–1.22)</td>
<td>0.10</td>
</tr>
</tbody>
</table>

BMI = body mass index; CI = confidence interval; OR = odds ratio.

*–2Logl = 218.833; Hosmer–Lemeshow χ²[8] = 7.30, p = 0.46. Final training model following 5 deletions.

†–2Logl = 215.370; Hosmer–Lemeshow χ²[8] = 7.74, p = 0.46. Final validation model following 3 deletions.

---

**Table 4. Additional analysis (PASS 2): training and validation, final models**

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training data set a*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.06 (1.03–1.10)</td>
<td>0.001</td>
</tr>
<tr>
<td>Global rating of pain</td>
<td>1.29 (1.12–1.50)</td>
<td>0.001</td>
</tr>
<tr>
<td>PASS 2</td>
<td>0.54 (0.25–1.15)</td>
<td>0.11</td>
</tr>
<tr>
<td>Willingness</td>
<td>3.77 (1.40–10.17)</td>
<td>0.009</td>
</tr>
<tr>
<td>Tried injections</td>
<td>1.79 (0.93–3.43)</td>
<td>0.06</td>
</tr>
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</table>

**Validation data set b†**

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.02 (0.99–1.06)</td>
<td>0.18</td>
</tr>
<tr>
<td>BMI</td>
<td>1.06 (1.00–1.11)</td>
<td>0.06</td>
</tr>
<tr>
<td>Bi/Uni Symptoms</td>
<td>0.50 (0.25–1.00)</td>
<td>0.06</td>
</tr>
<tr>
<td>Global rating of pain</td>
<td>1.12 (0.95–1.31)</td>
<td>0.17</td>
</tr>
<tr>
<td>PASS 2</td>
<td>0.23 (0.10–0.53)</td>
<td>0.001</td>
</tr>
<tr>
<td>Willingness</td>
<td>8.67 (2.64–28.48)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Tried injections</td>
<td>1.62 (0.82–3.21)</td>
<td>0.16</td>
</tr>
<tr>
<td>Allied health</td>
<td>0.43 (0.12–1.50)</td>
<td>0.19</td>
</tr>
</tbody>
</table>

BMI = body mass index; CI = confidence interval; OR = odds ratio.

*–2Logl = 226.117; Hosmer–Lemeshow χ²[8] = 7.74, p = 0.46. Final training model following 5 deletions.

†–2Logl = 205.917; Hosmer–Lemeshow χ²[8] = 7.75, p = 0.46. Final training model following 2 deletions.

---

**Table 5. Final clinical models, including the intercept**

<table>
<thead>
<tr>
<th>Intercept and variables</th>
<th>b</th>
<th>OR (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training data set a†</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>–6.163</td>
<td>1.00 (1.03–1.10)</td>
<td>0.001</td>
</tr>
<tr>
<td>Global rating of pain</td>
<td>0.26</td>
<td>1.29 (1.12–1.50)</td>
<td>0.001</td>
</tr>
<tr>
<td>PASS 2</td>
<td>–0.62</td>
<td>0.54 (0.25–1.15)</td>
<td>0.11</td>
</tr>
<tr>
<td>Willingness</td>
<td>1.33</td>
<td>3.77 (1.40–10.17)</td>
<td>0.009</td>
</tr>
<tr>
<td>Tried injections</td>
<td>0.58</td>
<td>1.79 (0.93–3.43)</td>
<td>0.08</td>
</tr>
</tbody>
</table>

**Validation data set b‡**

| Intercept              | –3.362| 1.02 (0.98–1.05)       | 0.32    |
| Global rating of pain  | 0.15  | 1.15 (0.99–1.35)       | 0.06    |
| PASS 2                 | –1.45 | 0.23 (0.10–0.53)       | < 0.001 |
| Willingness            | 2.21  | 8.67 (2.64–28.48)      | < 0.001 |
| Tried injections       | 0.50  | 1.65 (0.86–3.19)       | 0.13    |

CI = confidence interval; OR = odds ratio.

*The predicted probability of surgical candidacy can be calculated using the following formula: P(Surgical) = 1/(1+exp(–(–6.613 + Age × 0.58 + Global rating of pain × 0.26 + PASS 2 × 1.33 + Willingness × 1.33 + Tried injections × 0.58))). Continuous variables (Age, Global rating of pain) are entered directly. PASS 2, Willingness, and Tried injections are coded as Y = 1, n = 0.

†–2Logl = 226.117; Hosmer–Lemeshow χ²[8] = 7.74, p = 0.46. Final training model following 5 deletions.

‡–2Logl = 218.012; Hosmer–Lemeshow χ²[8] = 7.30, p = 0.46. Final training model following 5 deletions.

---

**Table 6. Sensitivities and specificities of the final model**

<table>
<thead>
<tr>
<th>Model</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 cut-off value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>0.78 (0.69–0.85)</td>
<td>0.63 (0.52–0.72)</td>
<td>70.9</td>
</tr>
<tr>
<td>Validation</td>
<td>0.85 (0.77–0.90)</td>
<td>0.58 (0.48–0.70)</td>
<td>73.9</td>
</tr>
<tr>
<td>0.35 cut-off value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>0.93 (0.86–0.97)</td>
<td>0.44 (0.34–0.55)</td>
<td>70.9</td>
</tr>
<tr>
<td>Validation</td>
<td>0.91 (0.83–0.96)</td>
<td>0.48 (0.37–0.59)</td>
<td>72.4</td>
</tr>
</tbody>
</table>

CI = confidence interval.
proceed with surgery; lacked advanced OA; was only mildly symptomatic; or had not yet tried or exhausted conservative therapies, such as physical therapy or injections, to manage their OA). The application of the model developed in this study would reduce the proportion of nonsurgical referrals by 25%, while identifying the vast majority of surgical candidates (> 90%). It may be useful for referring physicians to consider the predictors identified in our model when deciding if a referral for TKR is the most appropriate avenue for patients with knee OA. While not every patient referred to an orthopedic surgeon will be a candidate for surgical intervention, improving education for patients and practitioners regarding the timing of referral and conservative options may introduce a more efficient care pathway.

**Limitations**

A limitation of the present study is that the results may be specific to the study centre and its patient population. Our centre is located within an academic institution and is a high-volume joint-replacement centre whose surgeons operate almost exclusively within their designated specialty. Although there are similar centres in larger urban areas, the rate of referrals that are nonsurgical at their initial consultation may be slightly overestimated in comparison to referrals to an orthopedic surgeon whose practice includes nonsurgical interventions and/or a broader spectrum of diagnoses.

**Conclusion**

Before making a referral, physicians must ask patients about their willingness to undergo joint replacement surgery. If the patient is unwilling, but meets all other criteria for referral, the physician should investigate reasons for unwillingness (e.g., uncertain about what to expect during the recovery period, lack of support for ADLs during recovery period) and perhaps provide educational material and information about available support groups. Patients who are willing to undergo joint replacement, whose pain is greater than 4/10, who are dissatisfied with their current ability to function, and who are older than 50 years should be referred for TKR.

For patients with mild symptoms, the physician may offer pharmacological pain relief (e.g., acetaminophen, nonsteroidal anti-inflammatory drugs/COX inhibitors) with referrals made to clinicians with expertise in administering intra-articular injections (e.g., sports medicine physicians), physical therapy, nutrition and weight loss (Fig. 3).

Physicians should follow up with the patient regularly to identify changes in pain and function to reassess eligibility and willingness for joint replacement. Finally, physicians should use radiography (bilateral weight-bearing films) as a modifier to decision-making, where patients with severe degenerative changes are more likely to benefit from TKR. Magnetic resonance imaging should not be used to diagnose the degree of degenerative changes or meniscal pathology because it is expensive and provides minimal diagnostic benefit over plain films even in patients with mild to moderate knee OA.

Our study showed that 45% of patients referred to an arthroplasty surgeon are not suitable or “ready” surgical candidates at the time of initial consultation. A patient’s willingness to undergo surgery, previous injections, significant pain, physical disability and older age can correctly predict whether a patient is scheduled for TKR in 70% of referrals. Given long wait times for initial consultation and the potential additional costs to the patient and health care system, joint replacement represents an area where education to optimize referrals may better optimize patient care.

---

![Algorithm for patient referral to total knee replacement (TKR)](Fig. 3)
Affiliations: From the Research Department, Western University, London, Ont., (Churchill, Malian); the Department of Epidemiology and Biostatistics, School of Health Studies, Western University, London, Ont., (Chesworth); the Schulich School of Medicine & Dentistry, Department of Orthopaedic Surgery, Western University, London, Ont., (Bryant, MacDonald, Giffin); and the School of Health Studies, Faculty of Health Sciences, Bone and Joint Institute, Western University, London, Ont., (Marsh).

Competing interests: None declared.


L. Churchill, S. Malian, B. Chesworth, D. Bryant, S. MacDonald and J. Giffin wrote the article, which all authors reviewed and approved for publication.

References
7. CJRR. Hip and knee replacements in Canada: Canadian Joint Replacement Registry 2013 annual report. Ottawa (Ont.): Canadian Institute for Health Information (CIHI); 2013.
26. Thorstensson C, Dahlberg L. The BOA-Register: better management of patients with osteoarthritis, annual report; 2011.
An economic evaluation of the Enhanced Recovery After Surgery (ERAS) multisite implementation program for colorectal surgery in Alberta

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Anderson W. Chuck, PhD, MPH
Tracy Wasylak, MSc
Jeannette Lawrence, BScN, MBA
Peter Faris, PhD
Olle Ljungqvist, MD, PhD
 Gregg Nelson, MD, PhD
Leah M. Gramlich, MD

Background: In February 2013, Alberta Health Services established an Enhanced Recovery After Surgery (ERAS) implementation program for adopting the ERAS Society colorectal guidelines into 6 sites (initial phase) that perform more than 75% of all colorectal surgeries in the province. We conducted an economic evaluation of this initiative to not only determine its cost-effectiveness, but also to inform strategy for the spread and scale of ERAS to other surgical protocols and sites.

Methods: We assessed the impact of ERAS on patients' health services utilization (HSU; length of stay [LOS], readmissions, emergency department visits, general practitioner and specialist visits) within 30 days of discharge by comparing pre- and post-ERAS groups using multilevel negative binomial regressions. We estimated the net health care costs/savings and the return on investment (ROI) associated with those impacts for post-ERAS patients using a decision analytic modelling technique.

Results: We included 331 pre- and 1295 post-ERAS patients in our analyses. ERAS was associated with a reduction in all HSU outcomes except visits to specialists. However, only the reduction in primary LOS was significant. The net health system savings were estimated at $2,290,000 (range $1,191,000–$3,391,000), or $1,768 (range $920–$2,619) per patient. The probability for the program to be cost-saving was 73%–83%. In terms of ROI, every $1 invested in ERAS would bring $3.8 (range $2.4–$5.1) in return.

Conclusion: The initial phase of ERAS implementation for colorectal surgery in Alberta is cost-saving. The total savings has the potential to be more substantial when ERAS is spread for other surgical protocols and across additional sites.

Contexte : En février 2013, les Services de santé de l'Alberta ont mis en place le pro-gramme ERAS (Enhanced Recovery After Surgery — récupération postchirurgicale améliorée) dans le but de faire adopter les lignes directrices en matière d’interventions colorectales de la ERAS Society à 6 établissements (première phase) où sont pratiquées plus de 75 % des interventions chirurgicales colorectales de la province. Nous avons réalisé une évaluation économique du programme, non seulement pour en mesurer la rentabilité, mais aussi pour élaborer une stratégie visant à étendre le programme ERAS à d’autres protocoles chirurgicaux et services de chirurgie.

Méthodes : Nous avons mesuré les effets du programme ERAS sur l’utilisation des services de santé (durée de séjour, réadmissions, visites au service des urgences, visites d’un omnipraticien ou d’un spécialiste) dans les 30 jours suivant le congé en comparant les groupes pré- et post-ERAS à l’aide de régressions binomiales négatives multivariées. Nous avons évalué le coût net des soins de santé, les économies réalisées et le rendement sur investissement (RSI) associés aux mesures ci-dessus chez les patients post-ERAS à l’aide d’une technique de modélisation analytique décisionnelle.

Résultats : Nos analyses ont porté sur 331 patients pré-ERAS et 1295 patients post-ERAS. Nous avons observé une réduction de toutes les mesures de l’utilisation des services de santé étudiées, sauf les visites d’un spécialiste. Toutefois, seule la réduction de la durée du premier séjour était significative. Les économies nettes pour le système de santé ont été estimées à 2 290 000 $ (de 1 191 000 $ à 3 391 000 $), soit 1 768 $ (de 920 $ à 2 619 $) par patient. La probabilité que le programme soit économique était de 73 % à 81 %. En ce qui concerne le RSI, nous avons établi que chaque dollar investi dans le programme ERAS rapporterait 3,8 $ (de 2,4 $ à 5,1 $).
Enhanced Recovery After Surgery (ERAS) is an evidence-based multimodal care pathway that aims to attenuate surgical stress and has proven earlier recovery for patients undergoing major surgery. It is well documented that ERAS is clinically effective as well as cost-effective/cost-saving in that it reduces complications and health services utilization (HSU; e.g., length of stay in hospital [LOS]) without compromising patient safety and health-related quality of life (HRQoL). A recent meta-analysis of 16 randomized controlled trials shows that ERAS significantly decreases primary LOS by 2.28 days and risk of complications by 40% in patients undergoing colorectal surgery. Most recently, a cost-effectiveness study of ERAS for colorectal surgery showed that ERAS helped patients return to work sooner and lessened caregiver burden without lowering patients’ quality of life and that, societally, ERAS saved $2985 (range $373–$5753) per patient, with the probability for ERAS to be cost-effective at close to 100%. Most reports on implementation of enhanced recovery programs are single-centre studies and may or may not incorporate or audit for all ERAS elements. The Netherlands reported significant improvement using consensus guidance for a structured implementation program using a breakthrough methodology model from the Institute for Healthcare Improvement. In the United Kingdom, the National Health Service ran a national program of enhanced recovery in several disciplines based on lectures and protocols from leaders in enhanced recovery, leading to small but significant LOS savings.

The current ERAS implementation program used in Alberta is the first experience for a health system (including many surgical sites/centres) in North America evolved from the initial Dutch experience using a structure and well-defined implementation model based on local multidisciplinary and multiprofessional teams. Alberta Health Services (AHS) is Canada’s first province-wide, fully integrated health system, responsible for delivering health services to more than 4 million people. Provincial data reports that more than 275,000 surgical procedures are performed annually in 59 surgical facilities, with 11 of those performing 10,000–33,000 annual procedures. As part of its quality agenda, AHS uses Strategic Clinical Networks, groups of clinicians, managers, policy experts, researchers, patients and leaders, to drive innovation and research. Through the Diabetes, Obesity and Nutrition and the Surgery Strategic Clinical Networks, a demonstration project was funded to implement the ERAS Society colorectal guidelines and test them in the provincial health system with assistance from the ERAS Society’s endorsed ERAS implementation program. At the initial phase, between June 3, 2013, and Mar. 31, 2015, the implementation program included 6 hospitals/sites where more than 75% of all colorectal surgery in the province is performed. We conducted an economic evaluation of this initial phase of the Alberta ERAS implementation program to not only determine its cost-effectiveness, but also to inform strategy for synchronous structured implementation of ERAS expanding to multiple surgical specialties and sites across the province.

**Conclusion :** La première phase de la mise en œuvre du programme ERAS en Alberta, appliqué à la chirurgie colorectale, a été économique. Les économies pour le système de santé pourraient être plus importantes si l’on étendait le programme à d’autres protocoles chirurgicaux et services de chirurgie.

**Methods**

Within the ERAS implementation program, a database called “ERAS Interactive Audit System” had been developed for collecting pre-ERAS (conventional care) and post-ERAS data according to an evidence-based international guideline. The audit data scored compliance with the international guidelines to ensure adoption and limited variation among implementation sites across the health system.

We analyzed data from the pre- and post-ERAS patients recorded across the 6 early-adopter sites by the end of March 2015 together with the Alberta Health administrative databases, which provide information about LOS; readmissions; and visits to the emergency department (ED); specialists and general practitioners (GPs).

First, we assessed the impacts of ERAS on patients’ HSU within 30 days of hospital discharge by comparing pre- and post-ERAS patients. This time horizon allowed us to capture health system impacts in 5 areas: LOS during the time of surgery (primary LOS), inpatient readmissions occurring postdischarge (e.g., owing to a surgical complication), LOS for those readmitted, complications not requiring readmissions postdischarge presenting in an ambulatory setting (e.g., ED), and visits to a primary care provider in the community setting. Of note, these inpatient, outpatient and physician services also included rehabilitation services (if any). As these outcomes are count data and to account for random effects occurring among the 6 sites, we used multilevel (patients nested within sites) mixed-effects negative binomial regressions with random intercepts.

We measured the impacts of ERAS on HSU using incidence rate ratios (IRR) between post-ERAS patients (cases) and pre-ERAS patients (controls). We considered an IRR less than 1 to indicate that ERAS reduced HSU and vice versa. We considered results to be significant at $p < 0.05$. Patients’ demographic and perioperative characteristics were included as covariates in the negative binomial regression models analysis. These characteristics were age, sex, body mass index (BMI), smoking status, alcohol consumption, comorbidity, diagnosis, American Society of Anesthesiologists...
(ASA) physical status class, preoperative chemotherapy, surgical approach, surgical complexity (more complex group included abdominoperineal resection, anterior resection of rectum, total/subtotal colectomy, reversal of Hartmann procedure; less complex group included right hemicolectomy, left hemicolectomy, other large/small bowel resection, ileostomy reversal), blood loss, main procedure, year and hospital site. The $\chi^2$ test and $t$ test were used for comparisons of proportion and mean, respectively.

In the second step, we estimated health care costs/savings associated with impacts of ERAS calculated in the first step for the post-ERAS patients using a decision analytic modelling technique (Fig. 1). The costs/savings were estimated by multiplying the difference in HSU between cases and controls with the respective unit cost. We estimated the difference in HSU using the following formula: $D = HSU1 - HSU1 \times IRR$, where $D$ is the difference in HSU, $HSU1$ is the number of HSU of the controls, and $IRR$ is the impact of ERAS estimated by multilevel negative binomial regressions described in the first step. The unit cost can be cost per hospital day of primary LOS, cost per hospital day of readmission LOS, cost per ED visit, cost per specialist visit, or cost per GP visit, which was estimated using the data of pre-ERAS patients. We specifically used the pre-ERAS study cohort unit costs because if ERAS had not existed, the unit costs of post-ERAS patients would have been the same as those of pre-ERAS patients. To estimate the net costs/savings, we subtracted the ERAS intervention costs, including labour/coordination and licensing fees, which amounted to $826,210 or $638 per patient. Of note, there was no pay increase for doctors, surgeons and other medical staff participating in the ERAS implementation program. To estimate the return on investment ratio, we divided the total cost savings by the ERAS intervention cost.

In the base-case analysis, we conservatively included the significant impact (impact of ERAS on primary LOS) only. Furthermore, we did not use the average but the “marginal cost” per hospital day for the stays that were shortened by ERAS. The rationale was that during a hospital stay, the cost of health services in the last days of the stay is usually lower than the average and close to or equal to the “hotel cost” because of the high treatment cost in the first few days when major procedures (i.e., surgery) are done. As actual data were not available, we applied the “hotel cost” as a percentage of the average cost (43.5%, range 32.9%–58.8%), which we estimated based on micro-costing data of pre-ERAS colorectal surgeries in Montreal reported by Lee and colleagues, to the average cost of pre-ERAS patients ($1600) estimated from our data in order to estimate the marginal cost. Accordingly, the marginal cost estimated at $1566 (range $1184–$2117) was used in this study to estimate the cost savings of ERAS for shortening LOS (both primary and readmission).

Fig. 1. Decision tree to estimate health system savings. Savings1 = (LOS1 – LOS1 × IRR1) × c1, where LOS1 is primary LOS of pre-ERAS patients, IRR1 is the impact of ERAS on primary LOS measured by an IRR, and c1 is the marginal cost per hospital day of the primary LOS shortened by ERAS. Savings2 = (LOS2 – LOS2 × IRR2) × c2, where LOS2 is readmission LOS of pre-ERAS patients, IRR2 is the impact of ERAS on readmission LOS measured by an IRR and c2 is the marginal cost per hospital day of the readmission LOS shortened by ERAS. Savings3 = (ED – ED × IRR3) × c3, where ED is the number of ED visits of pre-ERAS patients, IRR3 is the impact of ERAS on ED visits measured by an IRR and c3 is cost per ED visit. Savings4 = (readmit – readmit × IRR4) × LOS2 × c4, where readmit is the number of readmissions of pre-ERAS patients, IRR4 is the impact of ERAS on readmissions measured by an IRR, LOS2 is readmission LOS of pre-ERAS patients, and c4 is the average cost per hospital day of readmissions prevented by ERAS. Savings5 = (SP – SP × IRR5) × c5, where SP is the number of specialist visits of pre-ERAS patients, IRR5 is the impact of ERAS on specialist visits measured by an IRR and c5 is the cost per specialist visit. Savings6 = (GP – GP × IRR6) × c6, where GP is the number of GP visits of pre-ERAS patients, IRR6 is the impact of ERAS on GP visits measured by an IRR and c6 is the cost per GP visit. ED = emergency department; ERAS = enhanced recovery after surgery; GP = general practitioner; IRR = incidence rate ratio; LOS = length of stay; SP = specialist.
Of note, this unit cost is comparable to those used in recent publications of the Alberta ERAS implementation program ($1114–$2106 in 2014, equivalent to $1127–$2131 in 2015 Canadian dollars) and to the marginal cost ($1237 in 2014, equivalent to $1271 in 2015 Canadian dollars) of patients undergoing hip and knee replacements in Alberta estimated by Alberta Bone and Joint Health Institute (unpublished data, but available upon request).

In a scenario analysis, we also included the statistically nonsignificant impacts of ERAS on other HSUs (readmission LOS, ED visits, specialist visits and GP visits) because the costs of these outcomes may still be substantial, as suggested by Stowers and colleagues. For the number of readmissions prevented by ERAS, as the whole LOS of each readmission was prevented, the average cost per day for readmission was used. The average cost per hospital day of readmission LOS ($2696), cost per ED visit ($904), cost per specialist visit ($352) and cost per GP visit ($196) were estimated from the data of pre-ERAS patients. As mentioned earlier, we used the pre-ERAS study cohort unit costs because if ERAS had not existed, the unit costs of post-ERAS patients would have been the same as those of pre-ERAS patients.

Sensitivity analysis

For the base-case scenario, we performed sensitivity analyses on 3 variables: the primary LOS of pre-ERAS patients, the impact of ERAS on this LOS and the marginal cost. In a deterministic 1-way sensitivity analysis, which allows 1 variable to vary at a time, the variation range was the 95% confidence interval (CI).

In a probabilistic sensitivity analysis that allows all variables to vary simultaneously, we analyzed 2 scenarios: 1) including only significant impact of ERAS on primary LOS (base-case scenario) and 2) including all statistically significant and nonsignificant impacts of ERAS on HSU. We assumed a normal distribution for impacts of ERAS (IRRs) and a γ distribution for LOS, numbers of HSU, and costs. We ran 100 000 samples and reported the probabilities for ERAS to be cost-saving.

We used Stata MP 13 (www.stata.com) for the impact analysis in the first step and TreeAge Pro 2015 (www.treeage.com) for the cost analysis in the second step. All costs were adjusted to 2015 Canadian dollars using the consumer price index.

RESULTS

In total, 1295 post-ERAS patients (cases) and 331 pre-ERAS patients (controls) who had colorectal surgery between 2013 and 2015 in 6 hospitals/sites across Alberta were included in our analyses. There was no significant difference in mortality between the 2 groups during the study period (0.23% of cases v. 0.30% of controls, p = 0.82). The demographic and perioperative characteristics of cases (post-ERAS) and controls (pre-ERAS) are shown in Table 1. There were no significant differences between the 2 groups in terms of demographic characteristics. We found some significant differences in terms of perioperative characteristics.

### Table 1. Demographic and clinical characteristics of patients in the pre-ERAS and post-ERAS groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Group</th>
<th>% or mean ± SD</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td>0.23</td>
</tr>
<tr>
<td>Age, yr</td>
<td></td>
<td>61.6 ± 13.8</td>
<td>0.26</td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td>28.5 ± 6.6</td>
<td>0.07</td>
</tr>
<tr>
<td>Smoker</td>
<td></td>
<td></td>
<td>0.48</td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
<td>0.48</td>
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<tr>
<td>Chemo therapy</td>
<td></td>
<td></td>
<td>0.98</td>
</tr>
<tr>
<td>Primary diagnosis</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Malignant neoplasm of colon</td>
<td></td>
<td>23.56</td>
<td>0.41</td>
</tr>
<tr>
<td>Malignant neoplasm of rectosigmoid junction</td>
<td></td>
<td>9.37</td>
<td>0.36</td>
</tr>
<tr>
<td>Malignant neoplasm of rectum</td>
<td></td>
<td>16.92</td>
<td>0.026</td>
</tr>
<tr>
<td>Benign neoplasm of colon, rectum, anus and anal canal</td>
<td></td>
<td>4.53</td>
<td>0.017</td>
</tr>
<tr>
<td>Crohn disease (regional enteritis)</td>
<td></td>
<td>6.04</td>
<td>0.012</td>
</tr>
<tr>
<td>Attention to artificial openings</td>
<td></td>
<td>18.43</td>
<td>0.13</td>
</tr>
<tr>
<td>No. of comorbidities</td>
<td></td>
<td>3.25 ± 3.55</td>
<td>0.030</td>
</tr>
<tr>
<td>No. of procedures</td>
<td></td>
<td>2.20 ± 1.92</td>
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</tr>
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<td>Main procedure</td>
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<tr>
<td>Intestine</td>
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<td>46.83</td>
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<tr>
<td>Rectal</td>
<td></td>
<td>30.82</td>
<td>0.81</td>
</tr>
<tr>
<td>Revision</td>
<td></td>
<td>22.36</td>
<td>0.87</td>
</tr>
<tr>
<td>Open surgery</td>
<td></td>
<td>46.72</td>
<td>&lt;0.001</td>
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<tr>
<td>Intraoperative blood loss, mL</td>
<td></td>
<td>216.1 ± 226.7</td>
<td>0.042</td>
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<tr>
<td>More complex surgery</td>
<td></td>
<td>40.48</td>
<td>0.10</td>
</tr>
<tr>
<td>Mortality</td>
<td></td>
<td>0.3</td>
<td>0.82</td>
</tr>
<tr>
<td>Year of surgery</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hospital/site</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Foothills Medical Centre</td>
<td></td>
<td>16.31</td>
<td>10.58</td>
</tr>
<tr>
<td>Grey Nuns Hospital</td>
<td></td>
<td>13.9</td>
<td>9</td>
</tr>
<tr>
<td>Misericordia Community Hospital</td>
<td></td>
<td>14.8</td>
<td>7.88</td>
</tr>
<tr>
<td>Peter Lougheed Centre</td>
<td></td>
<td>22.66</td>
<td>43.01</td>
</tr>
<tr>
<td>Royal Alexandra Hospital</td>
<td></td>
<td>17.52</td>
<td>7.57</td>
</tr>
<tr>
<td>University of Alberta Hospital</td>
<td></td>
<td>14.8</td>
<td>11.97</td>
</tr>
</tbody>
</table>

ASA = American Society of Anesthesiologists; ERAS = Enhanced Recovery After Surgery.
differences in pre- and intraoperative characteristics, including diagnosis, number of comorbidities, number of procedures, proportion of open surgery and amount of intraoperative blood loss. Specifically, post-ERAS patients had fewer malignant neoplasms of the rectum (12.28% v. 16.92%) but more benign neoplasms of the colon, rectum, anus and anal canal (8.42% v. 4.53%); slightly fewer comorbidities (mean 2.86 v. 3.25) and procedures (mean 2.01 v. 2.20); fewer open surgeries (35.75% v. 46.22%); and less intraoperative blood loss (mean 190.4 mL v. 216.1 mL).

Observed differences in years and hospitals/sites were owing to differences in the start time of ERAS implementation and in volume of patients among sites. The 2 sites with the largest volumes of colorectal surgery (Peter Lougheed Centre, Calgary, and Grey Nuns Hospital, Edmonton) were the first to start ERAS.

The HSU of controls (pre-ERAS), impacts of ERAS on HSU, average change per patient and total change for all post-ERAS patients are shown in Table 2. On average, a control patient stayed 9.04 days in hospital for the surgery (primary LOS). Within 30 days of discharge, control patients had an average of 0.55 ED visits, 2.65 specialist visits and 2.1 GP visits and were readmitted an average of 0.14 times with a mean readmission LOS of 10.1 days.

With the exception of specialist visits, all IRRs were less than 1, indicating that ERAS reduced all the HSU; however, only the reduction in primary LOS was significant. The average primary LOS of a post-ERAS patient was equal to 83% (95% CI 77%–89%) of a pre-ERAS patient. In other words, ERAS reduced 17% (95% CI 11%–23%) of primary LOS, equating to 1.5 (95% CI 0.99–2.1) days per patient or 1990 (95% CI 1288–2693) days for all 1295 patients.

Table 3 shows the numbers of days or visits reduced by ERAS, the unit cost for each health service, and the associated cost savings of ERAS in both the base-case and scenario analyses. In the base-case analysis, ERAS saved about $3 116 000 (range $2 017 000–$4 217 000) in HSU costs. Given the ERAS cost was approximately $826 000, the net cost savings of ERAS were estimated at $2 290 000 (range $1 191 000–$3 390 000) or $1768 (range $920–$2619) per patient. The return on investment ratio of ERAS was 3.8 (range 2.4–5.1) meaning that every $1 invested in ERAS would bring $3.8 (range $2.4–$5.1) in return.

In the scenario analysis where all outcomes (statistically significant and nonsignificant impacts of ERAS on HSU) were included, the net cost savings of ERAS was $3 019 000 or $2332 per patient. The return on investment ratio was 4.7, meaning that every $1 invested in ERAS would bring $4.7 in return.

The deterministic sensitivity analysis showed that the most sensitive variable was the impact of ERAS on the primary LOS. When the impact of ERAS on the primary

| Table 2. Impacts of ERAS on health services utilization within 30 days of discharge |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Outcome                        | Pre-ERAS        | IRR (95% CI)    | Average change (95% CI) | No. of patients | Total change, d (95% CI)* |
| Primary LOS, d                  | 9.04            | 0.83 (0.77 to 0.90) | -1.537 (-2.079 to -0.994) | 1295            | -1990 (-2690 to -1288) |
| No. of ED visits                | 0.55            | 0.92 (0.66 to 1.28) | -0.044 (-0.185 to 0.152) | 1295            | -57 (-240 to 197)      |
| No. of specialist visits        | 2.65            | 1.04 (0.84 to 1.29) | 0.106 (-0.432 to 0.756)  | 1295            | 137 (-560 to 979)      |
| No. of GP visits                | 2.1             | 0.96 (0.79 to 1.17) | -0.084 (-0.432 to 0.361) | 1295            | -109 (-560 to 467)     |
| No. of readmissions             | 0.14            | 0.99 (0.66 to 1.48) | -0.014 (-0.047 to 0.067) | 1295            | -18 (-61 to 67)        |
| Readmission LOS, d              | 10.1            | 0.71 (0.46 to 1.10) | -2.929 (-5.417 to 1.001) | 143             | -419 (-775 to 143)     |

CI = confidence interval; ED = emergency department; ERAS = Enhanced Recovery After Surgery; GP = general practitioner; IRR = incidence rate ratio; LOS = length of stay in hospital.

*Number of readmission was multiplied by the readmission LOS to get the total change in days.

| Table 3. Health care cost savings with ERAS (2015 Canadian dollars) |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Outcome                        | Total change, d | Unit cost       | Base-case analysis | Scenario analysis        |
|                                |                 |                 | Low             | High            |                  |
| Primary LOS, d*                | -1990           | $1566           | $3 116 340      | $2 017 008      | $4 217 238      |
| Number of ED visits            | -57             | $904            | 0               | 0               | $51 528         |
| Number of specialist visits    | 137             | $352            | 0               | 0               | -$48 224        |
| Number of GP visits            | -109            | $196            | 0               | 0               | $21 364         |
| Prevented readmissions         | -18             | $2696           | 0               | 0               | $49 528         |
| Readmission LOS, d             | -419            | $1566           | 0               | 0               | $656 154        |
| Total cost                     | $3 116 340      | $2 017 008      | $4 217 238      | $3 845 690      |
| Cost of ERAS                   | $826 210        | $826 210        | $826 210        | $826 210        |
| Total net cost savings         | $2 290 130      | $1 190 798      | $3 391 028      | $3 019 480      |
| Net cost savings per patient   | $1,768          | $920            | $2,619          | $2,332          |
| Return on investment ratio     | 3.8             | 2.4             | 5.1             | 4.7             |
LOS varied by the 95% CI (0.77–0.89), the net cost savings varied from $1 191 000 to $3 391 000 or $920 to $2619 per patient, and the return on investment ratio varied from 2.4 to 5.1, as mentioned earlier.

The probabilistic sensitivity analysis results show the probability for ERAS to be cost saving (Fig. 2). If only significant impact of ERAS on the primary LOS was included, the probability for ERAS to be cost saving was 73%. If all significant and nonsignificant impacts of ERAS on HSU were included, the probability was 83%.

**DISCUSSION**

Alberta Health Services provided a large health system that embraced rapid implementation of ERAS driven by the Strategic Clinical Networks. Alignment of system leadership and executive support of the frontline efforts required by the ERAS implementation program helped stimulate rapid uptake and interest across the province. The present study economically evaluated the ERAS implementation program and its adoption of the ERAS Society colorectal guidelines within AHS from June 2013 to March 2015 in 6 sites that perform more than 75% of all colorectal surgeries in the province. Our results show that ERAS significantly reduced the primary LOS, resulting in health care cost savings. In terms of return on investment, every $1 invested in ERAS would bring $3.8 in return. This finding is consistent with the results of 17 other studies, as reported in a review by Stowers and colleagues, and found that HRQoL does not differ between pre- and post-ERAS groups (0.3% v. 0.23%, p = 0.82), and other studies have demonstrated that HRQoL does not differ between pre- and post-ERAS patients.

Third, the health system savings of ERAS would be greater if benefits associated with “free capacity” were included. That is, there will be more space (hospital/ward/bed) and staff to serve other patients as ERAS shortens hospital LOS, saving health system resources, reducing wait times and thereby improving patients’ outcomes and satisfaction. Fourth, taking a health care rather than a societal perspective, as indirect cost (e.g., lost productivity) was not included, our study likely underestimated the total benefits of ERAS for society because by shortening hospital LOS, ERAS enables patients to return to work sooner. Finally, there may have been a selection bias as there were differences between pre- and post-ERAS patients (Table 1). However,
we believe that multivariate and sensitivity analyses minimize this bias. Also, the multilevel regression analysis can control for random effects among hospitals/sites.

**CONCLUSION**

The initial phase of the ERAS implementation program for colorectal surgery in Alberta was cost saving. The net health system savings were estimated at $2,290,000 (range $1,191,000–$3,191,000) or $1,768 (range $920–$2,619) per patient. The probability of the program being cost saving was estimated to be 73%–83%. In terms of return on investment, every $1 invested in ERAS would bring $3.8 (range $2.4–$5.1) in return. The total savings or return on investment may be more substantial when ERAS is spread to other surgical specialties and sites.

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**Contributors:** N. Thanh, A. Chuck, T. Wasylik, P. Faris, O. Ljungqvist, G. Nelson and L. Gramlich designed the study. N. Thanh, A. Chuck, T. Wasylik, J. Lawrence, P. Faris and G. Nelson acquired the data, which N. Thanh, A. Chuck, O. Ljungqvist and G. Nelson analyzed. N. Thanh, A. Chuck, T. Wasylik, J. Lawrence, O. Ljungqvist and G. Nelson wrote the article, which all authors reviewed and approved for publication.

**References**

Enabling front line–driven perioperative quality improvement through organizational infrastructure built around the Comprehensive Unit Based Safety Program

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Summary

Many surgical departments are interested in quality improvement (QI). For sustainable success, front-line involvement is crucial for improving culture. Without improved culture, any QI strategy will be a struggle. Designing an infrastructure to support these principles is important. We describe our process creating this infrastructure, the multidisciplinary teams that drive change in our department and some of the processes and outcomes we have been able to improve.

Quality improvement (QI) in surgery is a priority for many health care centres. Increasingly, hospitals are understanding that an underlying culture in which front-line health care workers are focused on quality is essential to sustainable, ongoing improvement. Many leaders like to talk about this concept, but we assert that if a centre wants to involve front-line providers, an infrastructure to enable this must be created. As Don Berwick stated, “a system creates the results it is designed to produce.” Without an infrastructure, there may be intermittent short-lived involvement; without sustained participation, culture will likely not improve.

A top–down type approach to improve quality in our department of surgery was initiated after data collected through the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) demonstrated a high surgical site infection (SSI) rate. During this time, there was minimal input from front-line staff and no improvement in the SSI rate. There was also a lack of surgeon ownership of this problem. The decision was made to use the Comprehensive Unit Based Safety Program (CUSP)\(^1\)\(^2\) as our method of engaging health care providers, improving culture and improving surgical processes across the spectrum of the patient journey.\(^1\) One of the most attractive aspects of CUSP to our group was its simplicity. Surgeons and other front-line providers easily understood the approach. People were able to get involved, have their ideas heard and start making changes. The relative ease of its implementation, the resulting quick wins and the flexibility in terms of issues it could address led to buy-in on multiple levels of our organization — the most important level being the front line. Our creation and implementation process is described in detail in Appendix 1, available at canjsurg.ca.

A CUSP team is a multidisciplinary team that in our institution is led by a dyad of a surgeon and nurse. The team members involved depend on the unit but should include anyone who comes into contact with the patients. Therefore, for the inpatient floor the CUSP team includes occupational therapists, physiotherapists, housekeeping staff, the ward clerk, front-line nurses, residents and others. Importantly, each team also includes a QI coordinator, who adds QI expertise to these front line–driven teams, and an engaged senior executive to facilitate change.
We started with 3 CUSP teams in the colorectal, vascular and orthopedic spine surgery fields in our department. With the quick wins we had in these areas, expansion continued to our current complement of 23 teams. Some of these teams are called “corporate” CUSP teams, as they address issues that are relevant across the entire department (e.g., antibiotics dosing, patient warming, blood glucose management). To ensure that teams can benefit from successes as well as lessons learned, we have monthly meetings in which the dyads are invited to share experiences as well as updates on new projects. A perioperative logistics team looks at the feasibility of proposed ideas that would incur substantial costs. Alignment of all these teams with the hospital and departmental vision occurs via an executive team that consists of our QI coordinators, senior executives from the hospital, department chairs of anesthesiology and surgery and front-line surgeons.

Ideas for improvement were solicited using a simple survey with the following questions. How will the next patient be harmed? What can be done to reduce this harm? Why do you think the next patient will get an SSI? What can we do to prevent the SSI? The 47 interventions that subsequently occurred were driven by the responses to the survey (Fig. 1).

A critically important result is that there are now 200 front-line health care providers involved in QI in surgery (as opposed to essentially zero when we first started). Surgical site infections across the department have not been solved, but in specific areas, such as bariatric surgery, the SSI rate has decreased from 10% to less than 1%. A new communication process was initiated on the general surgery inpatient floors and has led to decreased pages to residents, improved collaboration among the entire health care team and, not surprisingly, better patient experience scores. There has been improvement in initial dosing and redosing of antibiotics.

Warming of patients has improved, and there have been changes in wound management. Discharge rounds started on the general surgery inpatient floors and have spread beyond surgery to the internal medicine floors. We have even run an in situ simulation program for 22 surgeons and their teams to improve communication in the operating room.

Through the creation of an enabling infrastructure, we have been able to engage a multitude of front-line workers and their ideas. With CUSP now running for 3 years, sustainability has occurred because of the implementation of both small- and larger-scale projects; there is also now funding within the department to support surgeons. Health care providers have seen their ideas implemented and continue to see suggestions incorporated into improving the quality of care for patients. This has led to continued engagement and the incorporation of the idea of CUSP into the culture that exists in the department of surgery. Quality improvement is an ongoing process, and with our flexible infrastructure we feel we are well positioned to continue the journey improving the care of our patients.

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**Fig. 1.** Interventions spanning the spectrum of patient care. NSQIP = National Surgical Quality Improvement Program; OR = operating room; PACU = post-anesthesia care unit; Pau = pre-admit unit; SDC = same-day care.
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Contributors: All authors contributed substantially to the conception, writing and revision of this article and approved the final version for publication.

References

The Web-based CanMEDS Resident Learning Portfolio Project (WEBCAM): how we got started

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SUMMARY

The CanMEDS framework is ubiquitous in Canadian postgraduate medical education; however, training programs do not have a universal method of assessing competence. We set out to develop a novel portfolio that allowed trainees to generate a longitudinal record of their training and development within the framework. The portfolio provided an objective means for the residency program director to document and evaluate resident progress within the CanMEDS roles.

For nearly 2 decades the philosophical foundation of medical education in Canada has been oriented on the CanMEDS competencies, a framework that focuses on meeting the multifaceted needs of the Canadian health care consumer.1 Its indoctrination was swift. Training program accreditation both in medical schools and in postgraduate training programs focuses a keen eye on the development of trainees within the model. While the framework details the core and enabling competencies required of trainees, it does not provide facile guidance on how a program is meant to evaluate competency.2 An evidence-based evaluation framework is not known, the lack of which leaves individual training programs to determine how to track, measure, evaluate and assure the fulfillment of the CanMEDS competencies.

Those involved in the general surgery residency training program at the University of Ottawa recognized this problem. We sought to design an evaluation format in which trainees could track their development within the CanMEDS framework as well as allow the training program more objective evidence on which to evaluate the progress of residents. This was the concept behind the Web-based CanMEDS Portfolio Project (WEBCAM).

The first phase of the WEBCAM project involved a thorough program self-evaluation. We needed to first identify “activities” available to our residents within the current construct of the program that were felt to foster their development within the CanMEDS roles. An activity was defined as a discrete task (curricular or extracurricular) that a resident in the program could participate in during training. A committee with representation from staff and residents agreed on which CanMEDS competency1 was best represented by each of these activities. Within our program, a total of 43 activities were individually assigned to each of the CanMEDS roles.

In the second phase, we worked with a local software development team to design WEBCAM. The website design was focused on 3 principle concepts: 1) it would provide a platform customizable to any residency training program; 2) secure, remote access would be available for trainees and the residency training program director; and 3) reports of completed activities could be generated by and for each trainee. A study grant allowed WEBCAM to be built. The start-up cost was $7500, with an annual hosting fee of $100.
Each of the 7 CanMEDS competencies were used to label individual sections in the portfolio, with the previously identified associated activities listed within each section. Individual password-protected accounts for each of the 38 trainees in our program were created. We then held a brief orientation session to demonstrate the functionality and purpose of WEBCAM. Residents were then given the opportunity to record their participation and completion of the activities they performed over the course of a 12-month period. During this time residents were asked to evaluate the functionality and usefulness of WEBCAM.

The results were promising. Most (92%) of the residents felt that the portfolio was a good way to organize their training progress, with the majority noting that the act of recording activities took less than 1 hour of their time each month. The major advantage of the program highlighted in the qualitative feedback was that WEBCAM provided an instrument with which their fulfillment of the non–medical expert CanMEDS roles could be recorded. More encouraging was that residents using WEBCAM brought numerous new activities to the attention of the research team, reinforcing the notion that residents are regularly participating in extracurricular events that contribute to their development as well-rounded physicians. These activities were reviewed by the research committee and added to WEBCAM under the most appropriate CanMEDS role. Their addition to the website benefited other trainees who were then able to realize new ways in which they could improve the breadth of their training.

The recorded resident activities were used by the program director during the annual review of each resident. Progress within the CanMEDS competencies could be objectively tracked, and the program director found this useful to identify areas for improvement for individual residents and for the training program as a whole. Anecdotally the program director expressed the utility of WEBCAM in preparing the Final In-Training Evaluation Report (FITER) for graduating residents, which requires reporting on each resident within the CanMEDS framework. WEBCAM was seen as particularly valuable in ensuring continuity of records when a new program director is appointed. Learning portfolios have been used successfully in diagnostic imaging residency programs; however, they used a strategy of self-assessment within each role instead of defining categorical activities in which residents could participate.

One of the principle limitations of the design of this portfolio is that it ascribes activities to single CanMEDS competencies. Reviewing the key and enabling competencies for each of the CanMEDS roles shows that there is often overlap, and activities as we have assigned them could be argued to belong in different roles. This issue is mollified somewhat when it is recognized that the portfolio generates a complete record of activities that can be used by the training program in developing the FITER and by residents in their preparation of curricula vitae. In these instances, residents and program directors would have the flexibility to cross-recognize activities in association with various CanMEDS roles. Another limitation of WEBCAM as a portfolio is that it does not evaluate objective competency in each of the CanMEDS roles. Mere performance of the activity may not be correlated with competence in a specific CanMEDS role. Further work will be focused on determining how fulfillment of activities can either be evaluated based on performance or linked to global assessments of competency with tools such as validated 360 evaluations.

WEBCAM is our attempt to objectively document CanMEDS-centred training, with the long-term goal of establishing a practical and effective tool that the residency program director can use to assess longitudinal resident growth and performance of training within CanMEDS roles. We believe that the implementation of the WEBCAM portfolio has been a useful exercise and can be a platform that can be customized to any residency training program in any specialty.

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Competing interests: None declared.

Contributors: All authors contributed substantially to the conception, writing and revision of this article and approved the final version for publication.

References


Preoperative repeat endoscopy for colorectal cancer: What is its role and when is it necessary?

Although colonoscopy is the gold standard for the surveillance and diagnosis of colorectal cancer, preoperative repeat endoscopy is often used to ensure accurate tumour localization before surgery. For instance, a reported 40.5% of patients undergoing colorectal cancer surgery at a multi-institution tertiary care centre underwent preoperative repeat endoscopy between 2008 and 2011. The most common indications cited were tattooing of the lesion, optimal surgical planning and repeated therapeutic attempt. This practice has, in part, resulted from a shift in surgical management, with increasing reliance on minimally invasive techniques, but also from a lack of standardized guidelines on appropriate tumour localization and colonoscopic reporting. This often results in patients undergoing an unnecessary medical procedure during their preoperative evaluation. We discuss some of the issues surrounding the practice of preoperative repeat endoscopy as well as patient perspectives on the procedure. Our observations suggest that repeat endoscopy in the setting of colorectal cancer surgery may play a role in enabling transition of patient care between the initial endoscopist and the treating surgeon and in improving the patient experience. Patients with operable colorectal cancer appear to understand and support the current use of repeat endoscopy. However, improving preoperative care will require further research and ultimately the development of evidence-based clinical guidelines.

Summary

Many surgeons consider repeat endoscopy to be the standard of care for colorectal cancer; however, its utility in the preoperative setting is not well understood, especially given the lack of standardized guidelines on appropriate tumour localization and colonoscopic reporting. This often results in patients undergoing an unnecessary medical procedure during their preoperative evaluation. We discuss some of the issues surrounding the practice of preoperative repeat endoscopy as well as patient perspectives on the procedure. Our observations suggest that repeat endoscopy in the setting of colorectal cancer surgery may play a role in enabling transition of patient care between the initial endoscopist and the treating surgeon and in improving the patient experience. Patients with operable colorectal cancer appear to understand and support the current use of repeat endoscopy. However, improving preoperative care will require further research and ultimately the development of evidence-based clinical guidelines.

Although colonoscopy is the gold standard for the surveillance and diagnosis of colorectal cancer, preoperative repeat endoscopy is often used to ensure accurate tumour localization before surgery. For instance, a reported 40.5% of patients undergoing colorectal cancer surgery at a multi-institution tertiary care centre underwent preoperative repeat endoscopy between 2008 and 2011. The most common indications cited were tattooing of the lesion, optimal surgical planning and repeated therapeutic attempt. This practice has, in part, resulted from a shift in surgical management, with increasing reliance on minimally invasive techniques, but also from a lack of standardized guidelines on appropriate tumour localization, including tattooing, and optimal colonoscopic reporting among clinicians. However, despite its increasing use and potential role in correcting localization errors, the procedure itself carries inherent risk, may lead to patient discomfort, and is associated with a delay to definitive treatment. Given that the current evidence surrounding the utility of repeat endoscopy is limited, this raises important questions about its role in preoperative care and the need for evidence-based clinical guidelines that identify when a repeat endoscopy is necessary and when it is not. For instance, do patients who have an initial endoscopy along with radiographic imaging (e.g., staging computed tomography [CT] scan) require a subsequent endoscopy before surgery?

Recent studies have explored discrepancies between general surgeons’ and gastroenterologists’ perspectives on repeat endoscopy and variability in localization practices. However, as an intervention that may not be necessary in every case and that may increase the burden on patients receiving cancer care, it is important to also consider the patients’ understanding and perceptions of repeat endoscopy. Thus, we surveyed patients in our colorectal practice to further explore the role of repeat endoscopy and improve the quality and experience of preoperative care.
First, preoperative repeat endoscopy appears to play a role in improving care transitions. Most of our patients have their initial diagnostic colonoscopy at an external institution. This is reported as a common indication for preoperative repeat endoscopy given the variety of localization techniques used by endoscopists and the lack of standardization in endoscopic reports. In fact, Al Abbasi and colleagues found a decrease in the repeat endoscopy rate when the operating surgeon was consulted at the time of the initial endoscopy. The clinical reasoning behind tattooing and accurate localization of the lesion was well understood by patients, and they favoured the idea of having their surgeon perform a second endoscopy. Patients believed that this would give the surgeon a better understanding of their cancer and ultimately support operative planning. This finding raises a controversial issue with respect to who should perform the screening or diagnostic colonoscopies in order to improve efficiency of cancer care and reduce tumour localization errors.

Second, repeat endoscopy may improve the patient experience, specifically by playing a role in supporting patients’ confidence in their care. Most patients perceived the repeat endoscopy as a positive experience, as a means to obtain a second opinion and as a procedure that provides additional information to optimize treatment. Understandably, patients are often more receptive to doctors’ recommendations for endoscopic procedures deemed necessary to advance their care; however, patients’ opinions may differ depending on whether they experience adverse outcomes either after the colonoscopy or the ultimate surgery. Additionally, while repeat endoscopy contributes to a longer preoperative evaluation process, this may in fact help patients come to terms with their cancer diagnosis, which can often be difficult, since the time from diagnosis to treatment has become increasingly abbreviated with shorter wait time targets and the emergence of expedited programs (e.g., same-day diagnostic programs).

Finally, any concerns patients had with repeat endoscopy were overridden by their preoccupation with their cancer diagnosis, treatment and postoperative quality of life. The possibility of having to live with a colostomy or having chemotherapy and radiation was a major patient stressor. This highlights the importance of strengthening preoperative patient education, specifically with respect to ostomy care, as well as psychological support and postoperative follow-up. Our survey identified an opportunity to improve the psychosocial support offered to patients.

As a consequence of existing practice patterns and the lack of clinical guidelines on appropriate tumour localization and synoptic reporting, patients may need to endure a second medical procedure during the course of their cancer care. Since patients with cancer are particularly vulnerable and often defer decision-making to their health care providers, it is important to focus on patient education and transitions of care in this setting. Moreover, patient participation and widespread stakeholder engagement will be important to improving preoperative care for colorectal cancer in the future. For instance, should more general surgeons perform screening colonoscopies to improve continuity of care from diagnosis to treatment, or would improved psychosocial support for patients appropriately serve this need? Our observations provide insight into patient perspectives on repeat endoscopy and may be used to inform the development of standardized guidelines. Further research is necessary to better understand the rate of preoperative repeat endoscopy across the province as well as the conditions under which repeat endoscopy may be safely omitted. Decreasing the incidence of repeat endoscopy may also require reform of colonoscopy reporting.

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References

The International Association of Student Surgical Societies: creation and dissemination

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The Lancet Commission estimates that 5 billion people lack access to adequate surgical care.1 Surgeons are much needed in Africa, which lacks approximately 1 million health workers.2 In response to decreasing enrolment of surgical trainees,3 the University of Cape Town (UCT) Surgical Society was created in 2006 to foster interest in surgery.4 It later realized that students around the world were interested in global surgery — the intersection of surgery and public health.5 In light of this, the UCT program expanded to include programs within South Africa, in surrounding countries (i.e., Namibia and Botswana), and in high-income countries (HICs).4

The International Association of Student Surgical Societies (IASSS) was founded in 2011 to help improve surgical training for medical students in low- and middle-income countries (LMICs). Its primary objectives are building sustainable networks for mutually beneficial exchanges, supporting student-driven projects, understanding issues impacting student interest in surgery, promoting global fellowship, creating an elective database and providing assistance to student surgical societies. The IASSS is a unique student-led initiative trying to improve surgical care in LMICs.

SUMMARY

While initiatives exist to address the worldwide need for surgeons, none involve a student-driven solution from low- and middle-income countries (LMICs). In response to falling surgical residency enrolment in South Africa, the students at the University of Cape Town (UCT) founded the UCT Surgical Society and were subsequently instrumental in creating the International Association of Student Surgical Societies (IASSS). The IASSS currently includes 25 societies in 15 countries. Its primary objectives are building sustainable networks for mutually beneficial exchanges, supporting student-driven projects, understanding issues impacting student interest in surgery, promoting global fellowship, creating an elective database and providing assistance to student surgical societies. The IASSS is a unique student-led initiative trying to improve surgical care in LMICs.

The UCT and University of Witwatersrand Surgical Societies were the first student surgical societies in Southern Africa. Together with 6 subsequent surgical societies (University of Kwa-Zulu Natal, University of Namibia, University of Botswana, University of Stellenbosch, University of Pretoria, and Medical University of Southern Africa), the Southern African Student Surgical Society (SASSS) was established in 2013 and constitutes the African core of the IASSS.
The IASSS has been organized by region and is constructed around the adage, “Think globally, act locally.” Students at the University of Toronto, Canada, have helped to establish a presence in North America; students from the University of Bucharest, Romania, have established a presence in Europe; the Surgical Interest Network of Australia was the inaugural Australasian group; and the International Students Surgical Society of China and the Bangladesh Medical Students’ Society were the initial affiliates in Asia.

**Foster mutually beneficial — and ideally equitable — connections and exchanges around the world**

The IASSS helps establish equitable connections among student societies by recognizing that each has a unique set of objectives, needs and resources. This network enables the matching of member societies with complimentary needs.

**Create a thoughtful global platform for surgical electives**

The IASSS aims to foster long-term formal institutional relationships. The interest in international surgical electives from medical students in both LMICs and HICs is an opportunity to establish a platform to broaden the scope of clinical and scholarly experiences for students moving in either direction. An online database listing electives is being compiled.

**Provide support for scholarly student-driven projects to improve patient care and provide solutions to global surgical issues**

Collaboration between the University of Witwatersrand and UCT resulted in a research competition at the regional SASSS symposium in 2013. The University of Namibia Surgical Society started a research program focusing on quality improvement in rural areas.

The IASSS fosters student-driven solutions for improving surgical training in LMICs. An online open education project was started with videos to augment the learning of basic surgical skills to address common surgical pathologies that junior doctors in southern Africa are expected to manage. Such local student-driven educational initiatives can be disseminated regionally and internationally.

**Foster a better understanding of local and global issues impacting medical students with an interest in surgical specialties and create a sense of global fellowship**

The IASSS aims to provide support for medical students interested in becoming surgeons who are equipped to tackle not only their local challenges, but also global surgery issues. Its hope is to provide a forum for global awareness, mutual understanding and a sense of fellowship.

**Provide assistance to aspiring student surgical societies across the globe**

The UCT and University of Witwatersrand Surgical Societies have developed a “Surgical Society Starter Pack” to help prospective societies get up and running. Sustainability of a new society is a key objective. By fostering and integrating new societies within the IASSS, relationships will grow among members, thus enabling new societies to thrive.

One goal of the IASSS that bears special mention is the establishment of open discussions regarding equitable partnership. Students from LMICs have specific objectives, as do those from HICs. Open communication, led by LMIC societies, will allow development of thoughtful collaborations where, although all needs may not be met, an understanding of what could and should be done can be examined. Examples of equitable exchange may range from HIC elective students not taking away learning opportunities from local students to what learning opportunities LMIC elective students may expect. If the elective experience for LMIC students cannot allow for clinical equity, beneficial alternatives, including research, education and health administration, may be provided. These are the types of discussions that the IASSS should not only facilitate, but also mandate.

An important milestone in the growth of the IASSS was the inaugural international symposium in Cape Town. This 4-day symposium in 2014 was attended by 116 students from 21 academic institutions in 15 countries from 5 continents. The dominant message for the participants was that mutually beneficial collaborations can lead to critical innovations in global surgery (e.g., open online education). This inaugural meeting established a greater sense of fellowship and understanding among attendees from HICs and LMICs. The second IASSS Symposium was held in Australia in 2015, and the third took place in Namibia in 2016. In time, we will be able to better assess the longitudinal impact of the IASSS on its members and the global society.

**Conclusion**

The IASSS is a unique home-grown society with firm roots in African soil and an immense potential for impact on improving surgical expertise in LMICs. The driving force of this movement will be from invested local...
stakeholders, and the support will be from a global membership of likeminded, young future surgeons. Details on how to join the IASSS are available in Appendix 1.

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References
The University of British Columbia (UBC), Department of Surgery invites applications for the position of Head of the Division of General Surgery. We seek a leader who will direct and develop the teaching, research and service programs of the academic Division. The Division Head will have administrative academic linkages with all six health authorities in British Columbia.

The successful candidate will be accountable for fostering coordination and cooperative relationships within the Division among the University and the affiliated Health Authorities. The candidate also will be responsible for promoting and improving the standards of patient care, service, teaching and research on behalf of UBC and the affiliated Health Authorities, as well as ensuring that the Division of General Surgery plays a leadership role in the development of surgical services and research within British Columbia.

Applicants should have broad and proven administrative experience, substantial academic and clinical experience, a proven record of scholarly activity with demonstrated excellence in teaching and a commitment to undergraduate, graduate and post-graduate medical education. The successful candidate must be eligible for registration as a Surgeon with the College of Physicians and Surgeons of B.C. and must be a Fellow of the Royal College of Physicians and Surgeons of Canada.

Anticipated start date will be July 1, 2017.

For more information about the Department of Surgery, please visit www.surgery.ubc.ca

Please direct application letters, accompanied by detailed curriculum vitae and names of four references to:

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The University of British Columbia is Canada’s third largest university and consistently ranks among the 35 best universities in the world. Primarily situated in Vancouver, UBC is a research-intensive university and has an economic impact of $4 billion to the Provincial economy.

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