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The death of expertise (in medicine)

The views expressed in this editorial are those of the author and do not necessarily reflect the position of the Canadian Medical Association or its subsidiaries.

Expertise. Something we are supposed to have as physicians and surgeons. Something I always took for granted. But it seems society may not feel the same. There is some good and some bad to the concept. It no longer seems necessary to have any expertise to do very much in this world — even run a country. We are in a situation in society where people are rising to positions of power with little regard for anything except the final result and certainly without the credentials to be competent. I feel a little transparency in medicine is a good thing. Being questioned because of information patients find in Google searches may be tiring some days, but certainly ensures that the patient–physician dialogue is not “one way.”

However, some Google-driven nonscientists are killing people with medical fables, such as antivaccine rhetoric. The number of websites that appear legitimate but contain weird information seems to be expanding. These websites claim to give you information that “big medicine” is afraid to supply. The reader gets the impression that we, the medical establishment, are hiding information from them — much the way Trump ran his campaign. This sours the patient–physician relationship. Sources with official titles claim medical treatments kill more people than the actual diseases and that physicians supply these treatments only in order to make money. This is the ultimate fake news that is held up as “proof” that Western medicine does not work.

So how else is medicine being affected by the loss of the importance of expertise? Every week, I, like other academics, receive dozens of invitations to sit on review panels or editorial boards of sundry new journals. These journals are usually open-access efforts that are published by predatory publishers and have sometimes interesting, nearly accurate titles. When the onslaught of offers first started, I was tempted to participate, and feel I have been lucky not to be tainted. But the ongoing avalanche of new titles is not unlike the misinformation being given over the Internet, as described above. The dilution of control from a few publishing houses is not in itself a bad thing, but the dilution of expertise sitting on the review boards and the resulting quality of manuscripts is somewhat worrisome. We may have reached the true Internet model of “publish everything and let the reader sort it out” — but I don’t think the readers are aware that this is what is happening. Most readers of academic journals are still under the impression that articles are vetted, peer-reviewed and checked for validity. Even the old system had some difficulty guaranteeing those 3 tenets.

So, is open access an improper delivery mechanism? No, it is not. Are new journals something to be avoided? No, they are not. There is one thing, however, that is still needed in medicine both by the reader of articles and the publishing or editing teams that deliver scientific papers. Expertise.

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

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La disparition de l’expertise (en médecine)

Les opinions exprimées dans cet éditorial sont celles de l’auteur et ne représentent pas nécessairement celles de l’Association médicale canadienne ou ses filiales.

L’expertise. En tant que médecins et chirurgiens, nous devrions tous posséder cette qualité. C’est une notion que j’ai toujours tenue pour acquise. Mais il semble que la société ne soit pas du même avis. Le concept a du bon et du moins bon. Il ne semble plus nécessaire de posséder une expertise pour réussir dans le monde actuel — même pour diriger un pays. De nos jours, les gens atteignent des positions de pouvoir en ne se souciant que du résultat final, et certainement sans la formation nécessaire pour être compétents. Je crois qu’il est bon de faire preuve d’une certaine transparence en médecine. Il peut être fatigant de se faire poser des questions sur des renseignements trouvés sur Google, mais le fait que les patients s’informent donne lieu à un véritable dialogue.

Le problème, c’est que des non-scientifiques qui se basent sur des recherches Google tuent des gens avec leurs fables médicales. Pensez entre autres à la rhétorique anti-vaccination. On trouve de plus en plus de sites Web qui paraissent sérieux, mais qui contiennent des renseignements pour le moins étranges. Ces sites prétendent fournir de l’information que les « géants de la médecine » cherchent à garder secrète et donner au lecteur l’impression que nous, le monde médical, lui cachons des choses — de la même manière que Trump a mené sa campagne. Cela dégrade la relation médecin—patient. On lit dans des sources aux titres officiels que des traitements médicaux tuent plus de gens que les maladies elles-mêmes, et que les médecins n’offrent ces traitements que pour s’enrichir. Ce sont là des fausses nouvelles à l’état pur, présentées comme « preuves » que la médecine occidentale ne fonctionne pas.

Alors, comment la médecine est-elle touchée par la perte d’importance de l’expertise? Chaque semaine, comme bien d’autres universitaires, je reçois des dizaines d’invitations à siéger aux comités de révision ou de rédaction de toutes nouvelles revues. Il s’agit généralement de revues en accès libre qui contiennent des titres parfois intéressants et presque exacts, mais sont publiées par des éditeurs rapaces. Quand l’avalanche d’offres a commencé, j’ai eu envie de participer; heureusement, ma réputation n’a pas été ternie. Mais le déferlement constant de nouveaux titres n’est pas sans rappeler la désinformation sur Internet mentionnée plus haut. La dilution du contrôle de quelques maisons d’édition n’est pas une mauvaise chose en soi, mais la dilution de l’expertise dans les comités de révision, et la baisse de la qualité des manuscrits qui s’ensuit sont plutôt inquiétantes. Peut-être avons-nous atteint le vrai modèle d’Internet consistant à « tout publier et laisser le lecteur faire le tri »? Si oui, je ne crois pas que le lecteur soit au courant. La plupart des gens qui lisent des revues scientifiques croient encore que les articles sont approuvés et évalués par les pairs, et que leur validité est vérifiée. Pourtant, même avec l’ancien système, ces 3 principes étaient difficiles à garantir.


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A solution to gender inequity in surgery?
Better caregiving policies

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See the related review paper by Peel and colleagues on p. 58

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We have been talking about gender inequity in surgery for decades. Countless studies, opinion pieces and news articles later, we are still talking about it.

Attitudes toward women in surgery appear to be shifting in a positive direction. Why, then, do women still represent only 27% of surgeons in Canada? The answer may, at least in part, lie in the field’s inability to adequately accommodate caregiving duties, which are still disproportionately “women’s responsibilities” in our society. Although most Canadian academic centres now have paid maternity leave policies for trainees and faculty, these do not necessarily apply to surgeons working in the community, nor do they always reflect what occurs in practice. The perceived inability of the field to accommodate both personal and professional duties is often a significant deterrent to young women considering a career in surgery. In this commentary, we explore the need to address the “caregiver problem” as an important step toward achieving gender equity in surgery.

Summary

Attitudes toward women in surgery appear to be shifting in a positive direction. Why, then, do women still represent only 27% of surgeons in Canada? The answer may, at least in part, lie in the field’s inability to adequately accommodate caregiving duties, which are still disproportionately “women’s responsibilities” in our society. Although most Canadian academic centres now have paid maternity leave policies for trainees and faculty, these do not necessarily apply to surgeons working in the community, nor do they always reflect what occurs in practice. The perceived inability of the field to accommodate both personal and professional duties is often a significant deterrent to young women considering a career in surgery. In this commentary, we explore the need to address the “caregiver problem” as an important step toward achieving gender equity in surgery.
challenging for surgeons to be absent for extended periods of time. Providing clinical coverage when someone chooses to take time off for an extended period puts a substantial strain on programs that are already short-staffed. Coverage often falls to the remaining staff, many of whom are already working over capacity, and can create challenges for those who choose to take time off for parental leave.

For women in particular, parental leave may pose additional challenges. Following childbirth, there is a certain period of recovery time necessary, and choosing to breastfeed poses additional demands at the beginning of an infant’s life. Thus, women often have less freedom with regard to the timing of their parental leave, making it harder for their absence to be accommodated. Men, on the other hand, have fewer restrictions and are more easily able to adjust their time off to accommodate clinical needs. This may make finding coverage less challenging. Skills may also deteriorate after extended periods of time off, leading to longer training times for some trainees. For example, a study of American specialty boards found that in some programs, 6 weeks of parental leave resulted in up to a year of additional training time. This depends on specific board policies, many of which have defined limits on absences from training. The exact rationale behind these policies is unclear, but might have included factors such as “ensuring sufficient clinical and procedural experience [and] attempting to promote fairness and consistency” among residents.  

If we really want to challenge inequity in surgery, bolder steps need to be taken to address the “caregiver problem.” This will no doubt take some time and force us to ask some difficult questions. For example, surgical training tends to be most demanding during the years when many people might consider starting a family. So, are we starting to train surgeons too late, and are we taking too long to train them? We must also consider how to integrate caregiving into the profession more effectively. This means encouraging parents to actively share caregiving duties by advocating for better parental leave policies and practices for men and developing ways for women to more easily re integrate into training or practice. Another solution is improved access to childcare for health care staff (e.g., providing daycare services on hospital premises), as Canada is currently ranked one of the worst in the developed world in terms of both funding of and access to childcare.  

Perhaps gender inequity continues to be an issue in surgery not because we think women cannot be successful surgeons, but because many women would rather not be successful surgeons if it means having to give up other aspects of their lives that they consider important. Although we in no way wish to undermine the efforts of women currently in the field who are both surgeons and parents and whose efforts have allowed us to have this conversation, we will not achieve the critical mass of women we need in the profession until we consider gender equity as a broader, system-level problem. It will not be easy, but other demanding professions, such as law, business and politics, are already paving the way in reconsidering what it means to be a professional and a caregiver.  

Although women still disproportionately take on caregiving duties in our society, it is an issue that will ultimately affect us all as we begin to care for the aging baby boomer generation. Shifting our focus to developing more equitable solutions for caregiving will allow us to make major strides not only toward addressing the gender gap in surgery, but also a healthier and more just society.

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No. 3 Canadian General Hospital (McGill) in the Great War: service and sacrifice

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SUMMARY

During the Great War, McGill University fielded a full general hospital to care for the wounded and sick among the Allied forces fighting in France and Belgium. The unit was designated No. 3 Canadian General Hospital (McGill) and included some of the best medical minds in Canada. Because the unit had a relationship with Sir William Osler, who was a professor at McGill from 1874 to 1885, the unit received special attention throughout the war, and legendary Canadian medical figures, such as John McCrae, Edward Archibald and Francis Scrimger, VC, served on its staff. The unit cared for thousands of victims of the war, and its trauma care advanced through the clinical innovation and research demanded by the nature of its work. Although No. 3 Canadian General Hospital suffered tragedies as well, such as the deaths of John McCrae and Osler’s only son Revere, by the war’s end the McGill hospital was known as one of the best medical units within the armies in France.

Fig. 1. No. 3 Canadian General Hospital (McGill) on parade Apr. 22, 1915, on the McGill University Campus. The Duke of Connaught can be seen shaking hands with Colonel Birkett.

The news on Aug. 4, 1914, that the British Empire had declared war on Germany flashed across the whole of the Empire, and patriotic enthusiasm exploded to support what was thought to be a noble cause — protecting Belgian neutrality and stopping German militarism. Montreal, then the largest city in Canada and its leading academic centre, was not spared this excitement. McGill University, which was affiliated with 2 of the leading medical establishments of Canada, the Royal Victoria Hospital (RVH) and the Montreal General Hospital (MGH), began its patriotic service by providing hospitals and medical services to support the fighting men in what was
thought would be a brief war. Physicians, surgeons, nurses and even medical students from these institutions would go on to make up No. 3 Canadian General Hospital (McGill), hereafter referred to as No. 3 CGH. This facility would become internationally recognized because of its famed staff and numerous accomplishments.

At the outbreak of the Great War (1914–1919), McGill and its affiliated hospitals were already powerhouses of medical research and innovation in Canada. Dr. Henry S. Birkett was Dean of Medicine in 1914, and immediately on hearing that war had broken out, he began making plans to offer a full general hospital to be placed at the disposal of the Empire. This intention was communicated to the Minister of Militia and Defence, Sir Sam Hughes, who accepted Birkett’s offer of a full general hospital with 1040 beds.1

Much of the fame associated with the hospital at the time resulted from its affiliation with Sir William Osler, who had been on faculty at McGill and on staff at MGH from 1874 to 1884. In 1914, Osler was the Regius Professor of Medicine at Oxford University. Under his influence, the creation of No. 3 CGH was expedited, and his only son, Revere Osler, was offered a position as an assistant quartermaster within the McGill unit.1

No. 3 CGH was organized based on the academic medical (and sometimes military) leadership of the McGill faculty. Dr. Henry Birkett was made Commanding Officer after taking a King’s commission as a colonel. Lieutenant-Colonel James Elder was named the Officer in Charge of Surgery. Dr. John McCrae, a physician and poet, would be pencilled in for the post of Officer in Charge of Medicine. Many other members of the McGill unit, such as Edward Archibald, Francis Scrimger, Jonathan Campbell Meakins and John George Adami, who would later go on to fame, were placed in leadership positions. Seventy-two nurses were selected to go overseas with the unit: 36 from the RVH and 36 from the MGH, under the direction of the hospital matron, Katherine Osborne MacLatchy.1

Planning for the McGill unit started in the Fall of 1914 and ran through the Winter of 1915. Military training was carried out on the playing fields of the McGill campus, where doctors and nurses were taught to salute and drill in order to give medical practitioners a military bearing. Courses on modern military medical and surgical practice were taught in the lecture halls of McGill’s medical school and in conference rooms and auditoriums of the RVH and MGH. The University Club of Montreal, across Sherbrooke St. from the McGill campus, served as first officers’ mess for No. 3 CGH.1,2 After months of training, No. 3 CGH was officially mobilized on Mar. 5, 1915, as part of the Canadian Expeditionary Force.1,3

While the rest of No. 3 CGH trained, 2 of its members — now Major John (Jack) McCrae from the Department of Medicine at MGH and Captain Francis Scrimger — entered into active duty before the rest of their hospital comrades. Major McCrae, despite not having served in the military for more than 10 years, had many military connections because of his service in the South African War (1899–1902) as a gunner. Immediately on hearing news of the declaration of war while in England, he offered his services and began lobbying for a place in the artillery, which he found as the Medical Officer of the 1st Canadian Artillery Brigade. At the same time, Major McCrae was officially offered the position of Officer in Charge of Medicine, so he made an agreement with then Colonel Birkett to return to the No. 3 CGH when it arrived in France. Before leaving for the Canadian troop concentration centre in Valcartier, Que., Major McCrae had dinner with his old friend Sir Andrew MacPhail to discuss his upcoming military mission.7

Captain Francis Scrimger, who was a junior house surgeon at the RVH, was affiliated with the Royal Montreal Regiment and crafted a similar agreement to allow him to go overseas with the first contingent, which left from Quebec on Oct. 3, 1915, for Plymouth, England.4

These 2 illustrious members of No. 3 CGH would be the first of the unit
to experience the horror of the Great War at the Second Battle of Ypres in Belgium (Apr. 22 to May 25, 1915), where the first large-scale use of poison gas in the history of warfare was carried out. Both of these physician-soldiers would go on to earn their reputations because of their association with this battle. Captain Scrimger received the Victoria Cross (VC) after retrieving the wounded during the fighting; his citation described how he had shown “the greatest devotion to duty among the wounded at the front” during “very heavy fighting.” To this day, Scrimger is the only Canadian Medical Officer to have won the VC. Although McCrae did not receive any military decorations for valour, he perhaps has achieved a more lasting immortality through his poem “In Flanders Fields,” which was inspired by events during the Second Battle of Ypres.

While McCrae, Scrimger and the rest of the 1st Canadian Division were fighting at Ypres, training and preparation of No. 3 CGH continued in Montreal. On Apr. 22, 1915, the unit paraded before Prince Arthur, Duke of Connaught and Strathearn, on the McGill campus and was officially pronounced ready for duty. On May 6, 1915, the unit departed for England aboard the SS Metagama to the strains of “O Canada” for further training and preparation before arriving in the active theatre of war. During the voyage, 2 appendectomies were performed in an otherwise uneventful crossing.¹

On the night of June 17, 1915, the unit finally arrived in France after crossing the English Channel on the SS Huanchaco and disembarked at Boulogne. The hospital was set up in Dannes-Camiers, and by Aug. 7, 1915, was deemed ready to receive casualties. The first operation by No. 3 CGH in France was carried out by James Elder on Aug. 9, 1915.¹

On account of its close association with Sir William Osler, many dignitaries and the medical elite of the time would visit the hospital. Visits by Dr. Harvey Cushing, the renowned American neurosurgeon, were common, as on Oct. 31, 1916.¹ On July 20, 1915, the Prime Minister of Canada (1911–1920), the Right Honourable Sir Robert Borden, visited the unit.¹ On Sept. 4, 1915, Sir William Osler, who had been given the rank of Lieutenant-Colonel, visited the unit with his son, Revere.¹ Queen Amélie of Portugal would also visit the hospital in September 1915. Notable visitors to No. 3 CGH included Princess Victoria of Schleswig-Holstein and Queen Mary of England in July 1917.² The visitors did not distract from the true work of the unit — caring for the victims of war. While treating casualties from the heavy fighting at the Battle of Loos in September 1915, a McGill private described the week as “the busiest since we opened — a confusion to me of blood, gaping wounds, saline and bichloride.”¹ A medical student wrote that “all night I washed dirty, lousy boys — lads from our part of the world (Canada).” He “saw passing on a stretcher a still figure, covered with the Union Jack — another added to the long roll who die for Canada.”

The McGill medical students who came over with No. 3 CGH were enlisted as stretcher-bearers and orderlies. As typical medical students, they were keen to work with the staff surgeons of the hospital and often tried to get away from scut work on wards. Often they would remove themselves from their ward duties, much to the dislike of the nursing staff, such as Clare Gass, to observe procedures in the operating room. Later Gass would soften and admit that “the dear boys” had contributed much to the functioning of the No. 3 CGH.² Gass was also one of the first people to have seen McCrae’s poem, “In Flanders Fields,” copying it into her diary.¹

Not only did No. 3 CGH members produce some of the best memoirs and poetry of the Canadian experience during the Great War, they also produced major advances in trauma care. On Oct. 27, 1915, Major Edward Archibald carried out the first blood transfusion at No. 3 CGH from a volunteer donor of the unit.¹ On Nov. 6, 1915, Lieutenant-Colonel Elder remarked that
the unit had performed more than 500 operations for combat injuries and admitted more than 3000 patients. He also observed that “some of the smells of the wounds are awful and the necessary incisions gastly [sic].” Colonel Birkett noted that some of the “tissues are so rotten with infection that portions can be removed by the hand.” The unit continued to work out of its collection of tents at Dannes-Camiers until Colonel Birkett, along with Majors McCrae and Meakins, found a better and more permanent location at the old Jesuit College at Boulogne in November 1915. No. 3 CGH was ready for operations at its new location on 27 January 1916.

In addition to caring for the wounded and ill, members of No. 3 CGH carried out valuable research. Lieutenant-Colonel Elder kept meticulous diaries and notes during his service in France and later reported his findings and data in publications such as the Canadian Medical Association Journal. In June 1916, Elder published a seminal paper on “trench foot,” a condition that was plaguing the Allied armies as their troops spent miserable wet weeks in the muddy slime of the trenches. In it Elder noted incidentally that the No. 3 CGH had almost completely switched to chloroform as a general anesthetic agent from the traditional ether. In another paper published in 1917, Elder proposed that for patients in hemorrhagic shock, blood was the best fluid to give, although saline was able to tide the patient over until a transfusion could be arranged.

The unit would also report on some of the emerging horrors of modern warfare, including the clinical effects of poison gases, such as mustard gas, which appeared in 1917. They studied these effects via postmortem examinations conducted at the unit. The McGill unit produced other innovations, such as telephone probes to electrically guide the locations of foreign bodies. And in 1917, after a study of 146 cases, medical staff noted that infected hemothoraces should be drained as soon as possible to avoid the consequences of empyema. No. 3 CGH also created mobile surgical teams consisting of a surgeon, anaesthetist, nursing sister, and orderly, who could deploy forward to carry out emergency operations close to the front line.

No. 3 CGH would support the Easter Monday assault by the Canadian Corps in the Battle of Vimy Ridge on Apr. 9, 1917. By Apr. 10, the first casualties started arriving at No. 3, and by the end of the battle on Apr. 14, they had admitted about 2000 patients. Most of the wounds were from machine gun bullets, received as Canadian troops stormed the ridge.

After the Second Battle of Ypres ended in May 1915, McCrae returned to No. 3 CGH to take up his duties as Officer in Charge of Medicine. However, he would never be the same after the horrors he experienced at Ypres. He became withdrawn and often spent long hours away from the hospital riding Bonfire, his horse, with the constant companionship of Bonneau, the dog that adopted him. There is some evidence that McCrae wished to stay with his beloved artillery brigade, identifying himself more as a soldier and gunner than as a physician. When called “sir” by a wounded soldier, he would say, “Don’t call me sir or doctor; I am a soldier, just like you.” McCrae was promoted to the rank of Lieutenant-Colonel and made Consultant in Medicine to the British Expeditionary Force on Jan. 24, 1918.

However, before McCrae could take up the post, he contracted pneumococcal pneumonia, which quickly developed into meningitis. On Jan. 28, 1918, Lieutenant-Colonel John McCrae died without knowing the outcome of the war. The funeral was to be a large, but sombre affair; Colonel Elder remarked that it was “one of the most impressive funerals I have ever seen.” Following McCrae’s coffin on a gun carriage was his faithful horse, Bonfire. Many other distinguished mourners followed, including Lieutenant-General Sir Arthur Currie, the Commander of the Canadian Corps.

Lieutenant Revere Osler came to France with the unit, serving as its quartermaster. However, Osler longed for the more direct role of a war combatant and therefore transferred to the Royal Field Artillery unit as an artillery officer. During the gruelling, rain-soaked Battle of Passchendaele (also known as the Third Battle of Ypres), Revere was seriously wounded by shelling on Aug. 30, 1917. He was brought to a casualty clearing station for treatment after an evacuation that took several hours. Because of Osler’s fame, Dr. Harvey Cushing of the Harvard Unit and Dr. George W. Crile of the Western Reserve Unit were summoned to operate on his perforated colon and mesenteric vessels after a transfusion of whole blood was given. However, little could be done, and Osler died on Aug. 31, 1917. Sir William Osler went into deep mourning, and it is said that he was never the same after his son’s death, losing much of his well-known enthusiasm and passion for life.

By the end of the war, No. 3 CGH had admitted 81 689 medical patients and 52 389 wounded; even more astonishing, it had carried out 11 395 operations with a death rate of less than 1%. The unit ceased operations on May 29, 1919, and returned to Canada on July 2 of that year. Most of the unit members would return to Montreal and their hospitals and try to resume their lives and careers.

Major Francis Scrimger, VC, went on to become the Chairman of Surgery at McGill. A medical student would say of him that “despite his shuffling gait and unmilitary bearing, we were all a bit in awe of him, as he was the only VC winner that we knew.” Scrimger would later die of a myocardial infarction at his home in 1937. His wife, Nursing Sister Elaine Carpenter, never remarried. Of the war, Scrimger would say, “We won, but the
sacrifice, how awful it was." Scrimger’s own son would die during the Second World War.⁴

Major Edward Archibald became Surgeon-in-Chief at the RVH. He went on to become a world leader in thoracic surgery and trained Dr. Norman Bethune, another Great War veteran. Archibald served in the Second World War as the Surgical Advisor to all of the Canadian Army.⁸

No. 3 CGH members had mixed feelings about their service during the Great War: pride for what they had accomplished, sorrow about comrades and those many patients they had lost, and uncertainty about the future. Most would integrate back into civilian life as best they could and try to remember the good times of comradeship during the war. However, many would simply prefer not to talk about it. Authorities during the war considered No. 3 CGH to be “the best medical unit in France” and noted that “James McGill builded [sic] better than he knew.”¹¹

Today, throughout the RVH and the MGH are many plaques and displays that remind us of McGill’s proud service, accomplishments and sacrifices during the Great War through No. 3 CGH. The legacy of No. 3 CGH lives on today, with several staff surgeons within McGill University Health Centre serving as Regular Force Royal Canadian Medical Service surgeons. Nurses from the Canadian Forces Trauma Training Centre (East) also maintain this proud tradition of McGill’s contribution to the care of the Canadian Armed Forces.

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Competing interests: E.J. Harvey is the Chief Medical Officer of Greybox Healthcare (Montreal) and Chairman of the Board of NXTSens Inc. (Montreal). No other competing interests declared.

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

References
Process mapping as a framework for performance improvement in emergency general surgery

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Background: Emergency general surgery conditions are often thought of as being too acute for the development of standardized approaches to quality improvement. However, process mapping, a concept that has been applied extensively in manufacturing quality improvement, is now being used in health care. The objective of this study was to create process maps for small bowel obstruction in an effort to identify potential areas for quality improvement.

Methods: We used the American College of Surgeons Emergency General Surgery Quality Improvement Program pilot database to identify patients who received non-operative or operative management of small bowel obstruction between March 2015 and March 2016. This database, patient charts and electronic health records were used to create process maps from the time of presentation to discharge.

Results: Eighty-eight patients with small bowel obstruction (33 operative; 55 non-operative) were identified. Patients who received surgery had a complication rate of 32%. The processes of care from the time of presentation to the time of follow-up were highly elaborate and variable in terms of duration; however, the sequences of care were found to be consistent. We used data visualization strategies to identify bottlenecks in care, and they showed substantial variability in terms of operating room access.

Conclusion: Variability in the operative care of small bowel obstruction is high and represents an important improvement opportunity in general surgery. Process mapping can identify common themes, even in acute care, and suggest specific performance improvement measures.

Contexte : Les conditions dans lesquelles s’effectuent les interventions chirurgicales d’urgence sont souvent jugées trop pressantes pour que l’on puisse mettre au point des approches normalisées d’amélioration de la qualité. Malgré tout, la schématisation des processus, un concept largement appliqué à l’amélioration de la qualité en milieu manufacturier, est maintenant appliquée en santé. L’objectif de cette étude était de schématiser les processus suivis dans les cas d’obstruction du grêle afin de déterminer les aspects dont la qualité pourrait être améliorée.

Méthodes : A partir de la base de données pilote du programme d’amélioration de la qualité des chirurgies générales d’urgence de l’American College of Surgeons, nous avons recensé les patients ayant reçu un traitement chirurgical ou non chirurgical pour une obstruction du grêle entre mars 2015 et mars 2016. Nous avons aussi utilisé cette base de données, de même que les dossiers des patients et les dossiers médicaux électroniques, pour schématiser les processus suivis de l’arrivée à l’hôpital jusqu’au congé.

Résultats : Nous avons recensé 88 patients atteints d’une obstruction du grêle (33 soumis à une chirurgie, et 55 à un traitement non chirurgical). Les patients opérés ont présenté un taux de complications de 32 %. Les processus thérapeutiques de l’arrivée au suivi se sont avérés très détaillés et variables en durée; par contre, la séquence de soins était uniforme. Nous avons utilisé des stratégies de visualisation des données pour repérer les goulots d’étranglement au chapitre des soins, ce qui a révélé une variabilité substantielle dans l’accès au bloc opératoire.

Conclusion : La variabilité observée dans les soins chirurgicaux pour l’obstruction du grêle est élevée et représente une importante occasion d’amélioration en chirurgie générale. La schématisation des processus permet de dégager des thémes communs, même dans un contexte d’urgence, et met en lumière des possibilités précises d’amélioration du rendement.
Emergency general surgery conditions are often thought of as being too acute and unpredictable for the development of standardized approaches to quality improvement (QI). However, the surgical literature shows that delays in acute care can cause adverse outcomes and negatively affect the patient and their health care experience. Effective strategies to measure the process of acute care surgery may open opportunities to improve performance and optimize surgical outcomes in complex and vulnerable surgical populations.

William Edwards Deming revolutionized the manufacturing world and helped to transform Japanese automobile production when he introduced the concept of process mapping. Process mapping uses a technique that breaks down complex events into individual processes and evaluates how these processes can be made more efficient. The pioneering work of Dr. Deming is epitomized by understanding and learning to manage variation. Variation exists in all processes and people as well as in the outcomes that are produced in any given system. In his seminal work, he stratifies the concept of variation into common and special causes. Common causes of variance are predictable, expected and natural to the system. Identifying common causes is challenging; however, these variables (e.g., speed and runtime of electronic health records) generally do not require change strategies. Alternatively, special causes are new and unanticipated variables that cause variance, and these causes are defects within the system that necessitate improvement (e.g., different physician management strategies for clinical presentations).

Process mapping in health care involves following patients through their hospital journey and documenting every interaction they have with the hospital system. The method allows providers to notice the small steps before management and discharge and identify areas of high variation and bottlenecks for future improvement. Insights from process mapping have driven large QI advances in cardiac surgery, otolaryngology and orthopedic surgery.

We applied the first 3 steps of the Six Sigma methodology — Define, Measure, Analyze, Improve and Control (DMAIC) — the business world’s equivalent to the Plan, Do, Study and Act (PDSA) cycle, by measuring and analyzing variation in the patient experience of care to quantify acute care service delivery. Ultimately, our study aimed to use process mapping to deconstruct the surgical care of patients presenting to emergency general surgery services with acute small bowel obstruction (SBO). To our knowledge, process mapping has not yet been applied in evaluating the delivery of acute care surgery services.

Methods

Ethics approval was granted at our tertiary health care centre. We used the American College of Surgeons (ACS) Emergency General Surgery Quality Improvement Program (EQIP) pilot database to identify patients presenting to a single, large teaching hospital over a 1-year period (Mar. 1, 2015, to Mar. 1, 2016), for the nonoperative or operative management of SBO.

Inclusion and exclusion criteria were defined by the ACS EQIP pilot. Inclusion criteria were diagnosis of SBO by a physician, admission to hospital or observation unit and imaging consistent with SBO. Patients had to be older than 18 years and admitted to the general surgery acute care service. Exclusion criteria were SBO occurring within 4 weeks of pelvic surgery; SBO occurring secondary to a ventral, inguinal or femoral hernia; SBO secondary to Crohn’s disease; or SBO occurring more than 48 hours after a patient’s hospital admission.

The EQIP database as well as charts and electronic health records were used to create process maps for each patient from the time of onset of symptoms to the time of discharge. The time points for which we collected data included time to emergency department (ED) triage, assessment by an ED physician, computed tomography (CT) scan, general surgery consult request, assessment by a general surgeon, admission to the general surgery service, transport to the ward, operative case booking, arrival in the operating room (OR) and discharge. We also collected time of admission and discharge to the intensive care unit (ICU) where applicable. Data for most time points were gathered from paper charts; however, time to the ED and time of discharge are recorded electronically, so we collected these data from the electronic charts. We evaluated the process maps to identify important process issues and their potential impact on clinical outcomes. We used Microsoft Excel version 15.18 for statistical analysis.

Results

Patients presenting with SBO at our tertiary level 1 trauma centre, Vancouver General Hospital, between Mar. 1, 2015, and Mar. 31, 2016, were stratified into 2 groups based on their treatment and management (Fig. 1). A total of 88 patients were included: 33 (40%) were managed operatively, and 55 (60%) were managed conservatively. The differences in the mean age (66.3 ± 17.6 yr v. 67.5 ± 17.3 yr, p = 0.75) and sex (21 [57%] men v. 29 [53%] men, p = 0.70) between the operative and conservative management cohorts, respectively, were not statically significant. Similarly, the difference in medical comorbidities between the groups was not significant (Table 1).

Evaluating the mean process intervals and standard deviations of conservatively managed patients showed an unexpectedly high degree of variation in the time interval of care for patients with SBO (Table 2). The greatest amount of variability was in transferring these patients to the ward after admission to the acute care surgery service (259 ± 257 min). There was also a longer time and variability associated with time from emergency physician evaluation and...
Fig. 1. Mapping the process and flow of a patient with small bowel obstruction from presentation to the emergency department (ED) to discharge from the acute care surgery service. Nonoperatively managed patients are represented in the top map, and operatively managed patients are represented in the bottom map. CT = computed tomography; ICU = intensive care unit; OR = operating room.
CT scan request (112 ± 171 min), which remains the mainstay and gold standard of diagnosis of SBO. The interval between being seen by an ED physician and receiving a consult with the acute care surgery team was also longer and unpredictable.

The process intervals of the operatively managed patients show similar trends of variability (Table 3). The period of time between evaluation by the ED physician and request of CT scan (121 ± 153 min) and between triage and being seen by an ED physician (74 ± 76 min) had greater degrees of variation. In addition, the time required to complete the consult (114 ± 167 min), to admit the patient to the acute care surgery service after the consult (165 ± 220 min) and to arrive in the OR after booking (442 ± 400 min) were also identified as areas in the patient’s stay that faced increased variability.

In addition to reviewing the journey of surgical patients through the hospital, we also further stratified the time from OR booking to arrival at the OR to assess the efficiency of the acute care service in meeting expected intervals based on the patient’s priority level (Table 4). Patients booked as an E1 owing to hypovolemic shock or peritonitis in the context of an SBO are our highest priority, meaning they should arrive in the OR within 1 hour of booking; these patients never arrived at the OR within the expected time limits. Most patients were booked as an E2 (arriving in the OR within 8–12 h of booking); although 69% of these patients arrived within the expected interval, there was a higher rate of variability and the mean was outside the expected 720 min (746 ± 893 min). Finally, the ACS service has protected OR time, and of the cases completed during these times, 80% were within their booked priority level’s time expectations.

**Discussion**

Variation in the clinical setting is unavoidable, and although some variation is expected owing to the complexity of cases and individual patient characteristics, there are differences in productivity, utilization of services and flow. Adding capacity and ORs addresses only part of this variation, and a deeper assessment of how patients flow through the system can further assist in identifying obstacles and bottlenecks that can be improved. Length of stay and waiting times have become benchmarks of quantifying clinical outcomes; however, our study further stratifies the overall hospital experience into granular periods of time that represent the steps in the clinical management of patients with SBO.

In our study and hospital environment, a source of variation in the operative and conservative management strategies of patients with SBO was during the time in the ED. Delays in requesting clinical imaging led to increases in mean time and variability in initiating an acute care surgery team consult. Additionally, these delays also led to downstream effects for the acute care surgery team and their ability to assess the patient and make relevant clinical decisions about management and treatment.

Another area of clinical variation was in getting our operatively managed patients to the OR. Although this is a well-established barrier affecting surgeons globally,17 we found that most of the high-priority cases were not getting to the OR in the expected intervals largely because of capacity issues. However, the acute care surgery service at our institution has protected OR time that can be used for urgent cases, and our findings show that this time was being used effectively. The protected time led to patients receiving their surgeries within the expected interval who may not have if it was not for the dedicated time set aside for the acute care surgery teams. Our sample size for this finding is small and reflects a need for further data collection and analysis.

**Table 1. Demographic and clinical characteristics of the operative and conservative management cohorts of patients with small bowel obstruction**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Group; mean ± SD or no. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Operative, n = 33</td>
</tr>
<tr>
<td>Age, yr</td>
<td>66.3 ± 17.6</td>
</tr>
<tr>
<td>Male sex</td>
<td>21 (56.8%)</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>4 (10.8%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>16 (43.2%)</td>
</tr>
<tr>
<td>Acute renal failure</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Ascites</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>COPD</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Disseminated cancer</td>
<td>1 (2.7%)</td>
</tr>
<tr>
<td>Steroid use/immunosuppression</td>
<td>3 (8.1%)</td>
</tr>
</tbody>
</table>

COPD = chronic obstructive pulmonary disease; SD = standard deviation.

**Table 2. Mean process interval outcomes for conservative (nonoperative) management of small bowel obstruction**

<table>
<thead>
<tr>
<th>Process interval measured</th>
<th>No.</th>
<th>Time, min; mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time from arrival in ED to triage</td>
<td>55</td>
<td>11 ± 10</td>
</tr>
<tr>
<td>Time from triage to emergency physician consult</td>
<td>55</td>
<td>74 ± 59</td>
</tr>
<tr>
<td>Time from emergency physician to general surgery consult initiation</td>
<td>55</td>
<td>198 ± 115</td>
</tr>
<tr>
<td>Time from emergency physician consult to CT request</td>
<td>48</td>
<td>112 ± 171</td>
</tr>
<tr>
<td>Time from CT request to acquisition</td>
<td>49</td>
<td>122 ± 99</td>
</tr>
<tr>
<td>Time from general surgery consult initiation to completion</td>
<td>49</td>
<td>92 ± 79</td>
</tr>
<tr>
<td>Time from consult to admission to general surgery service</td>
<td>49</td>
<td>114 ± 101</td>
</tr>
<tr>
<td>Time from admission to general surgery service to ward</td>
<td>52</td>
<td>259 ± 257</td>
</tr>
<tr>
<td>Overall length of stay</td>
<td>55</td>
<td>83 ± 51</td>
</tr>
</tbody>
</table>

CT = computed tomography; ED = emergency department; SD = standard deviation.

*Denominator varies slightly owing to missing data.

†Reported in hours rather than minutes.
The importance of investigating flow and process intervals in patient care is an emerging field in the era of increasing health expenditure and increasing operative and nonoperative complexity of patients. The EQIP pilot program to collect both operative and nonoperative patient outcomes allowed for robust data collection. To our knowledge, this is the first time such robust data collection strategies have been applied to nonoperative patients who are managed by surgical teams. Although there were initial errors that required correction through detailed chart reviews, the program extended the realm of patients who could be studied to improve quality and safety. From our experience, we discovered that these data were not difficult to collect and eventually led to insights that could build efficiencies in the system. Ultimately, collection of process mapping and understanding existing variation in the health system provides services with the ability to create effective data-driven solutions and the capacity to evaluate the impact of incremental changes on workflow processes.

Limitations

A limitation of this study is the retrospective nature of data collection, which led to some missing data when reviewing paper medical records. Additionally, even time stamps recorded on the electronic health record for certain points of care were subject to reporting bias. Potential delays around time to CT may be a result of receiving laboratory results, such as renal function, at a later time, leading to a delay in ordering a contrast CT; however, because of the way this is reported, these data cannot be collected, and the impact of timeliness of laboratory results on time to imaging is unknown.

Additionally, our results are specific to our site and should not be generalized to other institutions; however, the methodology could be applied easily to any other system. The population we investigated was specific to a single condition and part of a pilot EQIP project at our hospital, resulting in a small sample size, particularly in our operative group. Future work will be directed at larger groups of surgical patients with the hope of minimizing missing data and generating areas of QI and monitoring. We hope our work inspires other centres to follow similar methodologies to discover areas of improvement for surgical patients.

Future work

In the future, an electronic platform could be adapted to track patient care and document points of care in the patient’s journey through the hospital system. With this platform, the general surgery service could have access to real-time data to monitor metrics and evaluate how new QI interventions are working within our system, while simultaneously flagging new areas for intervention. Additionally, investigating the impact of meeting expected intervals based on the patient’s priority level and its impact on patient outcomes could help to further justify the need for protected emergency general surgery OR time.

A strategy to improve flow in the ED would be to add preprinted orders (PPOs) that summarize the evidence-based steps of the initial workup of a suspected case of an SBO. Using the PPO, the emergency physician would be able to start several treatment options and order imaging and laboratory tests critical to management of patients with SBO before general surgery consultation. This could potentially streamline and standardize the initial workup, thus improving flow through the department, while providing timely and pertinent clinical information to facilitate the acute care surgery team’s decision-making. For instance, the initial PPO laboratory investigations will include relevant kidney function tests that may address the delay in ordering CT imaging with contrast.

<table>
<thead>
<tr>
<th>Table 3. Mean process interval outcomes for operative management of small bowel obstruction</th>
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</thead>
<tbody>
<tr>
<td>Process interval measured</td>
</tr>
<tr>
<td>Time from arrival in ED to triage</td>
</tr>
<tr>
<td>Time from triage to emergency physician consult</td>
</tr>
<tr>
<td>Time from emergency physician consult to general surgery consult initiation</td>
</tr>
<tr>
<td>Time from emergency physician consult to CT request</td>
</tr>
<tr>
<td>Time to CT request to acquisition</td>
</tr>
<tr>
<td>Time from general surgery consult initiation to completion</td>
</tr>
<tr>
<td>Time from consult to admission to general surgery service</td>
</tr>
<tr>
<td>Time from admission to general surgery service to ward</td>
</tr>
<tr>
<td>Time from OR booking to arrival to the OR</td>
</tr>
<tr>
<td>Time from OR to ward postoperatively</td>
</tr>
<tr>
<td>Overall length of stay†</td>
</tr>
</tbody>
</table>

| CT = computed tomography; ED = emergency department; OR = operating room; SD = standard deviation. |
| Denominator varies slightly owing to missing data. |
| *Reported in hours rather than minutes. |

<table>
<thead>
<tr>
<th>Table 4. Arrival in OR based on priority levels in operative management of small bowel obstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Priority level</td>
</tr>
<tr>
<td>E1 (&lt; 60 min from booking)</td>
</tr>
<tr>
<td>E2 (&lt; 480–720 min from booking)</td>
</tr>
<tr>
<td>E3 (&lt; 4320 min from booking)</td>
</tr>
<tr>
<td>Protected OR time</td>
</tr>
</tbody>
</table>

| OR = operating room; SD = standard deviation. |

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Conclusion

Quality improvement is the new science of health care, and our patients expect a “culture of safety” from their health care providers. This represents an exciting time for surgeons to be leaders in safer patient care. Process mapping is a simple way to evaluate a cohort of patients’ journeys through the hospital to identify areas for future interventions as well as track the impact of QI projects. Our cohort of patients with SBO are the first group, to our knowledge, to be analyzed using this method, and we hope to expand to more emergency general surgery patients in the future.

Acknowledgements: The authors thank Ms. Jillian Aquino for her design and creation of the figure.

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Competing interests: None declared.

Contributors: K. DeGirolamo, K. D’Souza, W. Hall and M. Hameed designed the study. K. DeGirolamo, K. D’Souza, N. Garraway and P. McLaughlin acquired the data, which K. DeGirolamo, K. D’Souza, E. Joos, C. Sing and M. Hameed analyzed. K. DeGirolamo, K. D’Souza, W. Hall and M. Hameed wrote the article, which all authors reviewed and approved for publication.

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Analysis of postdischarge costs following emergent general surgery in elderly patients

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Background: As populations age, more elderly patients will undergo surgery. Frailty and complications are considered to increase in-hospital cost in older adults, but little is known on costs following discharge, particularly those borne by the patient. We examined risk factors for increased cost and the type of costs accrued following discharge in elderly surgical patients.

Methods: Acute abdominal surgery patients aged 65 years and older were prospectively enrolled. We assessed baseline clinical characteristics, including Clinical Frailty Scale (CFS) scores. We calculated 6-month cost (in Canadian dollars) from patient-reported use following discharge according to the validated Health Resource Utilization Inventory. Primary outcomes were 6-month overall cost and cost for health care services, medical products and lost productive hours. Outcomes were log-transformed and assessed in multivariable generalized linear and zero-inflated negative binomial regressions and can be interpreted as adjusted ratios (AR). Complications were assessed according to Clavien–Dindo classification.

Results: We included 150 patients (mean age 75.5 ± 7.6 yr; 54.1% men) in our analysis; 10.8% had major and 43.2% had minor complications postoperatively. The median 6-month overall cost was $496 (interquartile range $140–$1948). Disaggregated by cost type, frailty independently predicted increasing costs of health care services (AR 1.76, 95% confidence interval [CI] 1.43–2.18, p < 0.001) and medical products (AR 1.61, 95% CI 1.15–2.25, p = 0.005), but decreasing costs in lost productive hours (AR 0.39, p = 0.002). Complications did not predict increased cost.

Conclusion: Frail patients accrued higher health care services and product costs, but lower costs from lost productive hours. Interventions in elderly surgical patients should consider patient-borne cost in older adults and lost productivity in less frail patients.

Trial registration: NCT02233153 (clinicaltrials.gov).

Contexte : Avec le vieillissement de la population, les personnes âgées seront plus nombreuses à subir des chirurgies. Il est déjà reconnu que la fragilité et les complications font augmenter les coûts d’hospitalisation chez les adultes âgés, mais on en sait relativement peu sur les coûts posthospitaliers, particulièrement ceux assumés par le patient lui-même. Nous avons analysé les facteurs de risque d’augmentation de ces coûts et les types de dépenses assumées après le congé par les patients âgés opérés.

Méthodes : Pour l'étude, nous avons recruté des patients de 65 ans et plus qui allaient subir une chirurgie abdominale d’urgence. Nous avons déterminé leurs caractéristiques cliniques initiales, y compris leur score à l’échelle de fragilité clinique (EFC). Nous avons calculé les coûts échelonnés sur 6 mois (en dollars canadiens) rapportés par les patients après leur congé, selon un inventaire valider de l’utilisation des ressources de santé. Les paramètres principaux étaient le montant total des dépenses et le coût des services de santé, des produits médicaux et des heures de travail perdues pour une période de 6 mois. Une transformation logarithmique a été appliquée aux données, qui ont été évaluées par une analyse de régression linéaire multivariée généralisée et par une analyse binomiale négative avec surreprésentation des zéros. Les résultats peuvent être interprétés comme des rapports ajustés (RA). Les complications ont été évaluées selon la classification de Clavien–Dindo.

Résultats : Nous avons inclus 150 patients dans notre analyse (âge moyen : 75,5 ± 7,6 ans; proportion d’hommes : 54,1 %). Après l’opération, 10,8 % ont présenté des complications majeures, et 43,2 %, des complications mineures. Le montant total médian des dépenses sur 6 mois était de 496 $ (éventail interquartile : 140–1948 $).
Dans les analyses effectuées selon le type de dépenses, la fragilité était une variable explicative permettant de prédire indépendamment l’accroissement des coûts des services de santé (RA : 1,76; intervalle de confiance [IC] à 95 % : 1,43–2,18; p < 0,001) et des produits médicaux (RA : 1,61; IC à 95 % : 1,15–2,25; p = 0,005) ainsi que la réduction des coûts associés aux heures de travail perdues (RA : 0,39; p = 0,002). Les complications n’avaient pas de valeur prédictive en ce qui a trait à l’accroissement des coûts.

Conclusion : Les patients fragiles ont assumé des coûts plus élevés en services de santé et en produits médicaux, mais des coûts moindres en lien avec la perte d’heures de travail. Les interventions chez les patients en chirurgie âgés devraient tenir compte des coûts assumés par cette population et de la perte de productivité chez les patients moins fragiles.

Enregistrement de l’essai : ClinicalTrials.gov, no NCT02233153

METHODS

Population and baseline data collection

Our cohort includes patients who were enrolled during the preimplementation period of a controlled before-and-after care transformation, the Elder-Friendly Approaches to the Surgical Environment (EASE) study (clinicaltrials.gov identifier: NCT02233153). Patients were prospectively recruited at 2 tertiary referral teaching hospitals in Alberta, Canada, with 1450 inpatient beds combined and more than 1 million unique patient visits per year (University of Alberta Hospital and Foothills Medical Centre). Patients were enrolled during index admissions between January 2014 and September 2015 if they required emergency abdominal surgery and were aged 65 years or older. Exclusion criteria were elective, trauma or palliative surgery, transfers from out of jurisdiction or other hospital services, and preoperative dependence in 3 or more activities of daily living. The health research ethics boards at each site approved our study procedures (Pro00047180). All study participants provided informed consent.

We collected demographic and clinical characteristics by performing detailed chart reviews or conducting follow-up interviews. We assessed frailty before admission, as defined by the revised Canadian Study of Health and Aging Clinical Frailty Scale (CFS; scores ranging from 1 [very fit] to 6 [moderately frail], as severely frail or terminally ill patients [CFS scores of 7–9] were ineligible for this study). For each patient, we calculated the Charlson Comorbidity Index and the Clavien–Dindo classification of surgical complications (grades III–V refer to major complications and grades I–II refer to minor complications). Complications that occurred postoperatively were included, but those that occurred on postoperative day 0 that were related to the admission diagnosis were excluded.
Surgical complications were independently and blindly assessed by 2 clinicians (G.E. and R.K.), with disagreement resolved by consensus. All-cause readmissions within 6 months of discharge were also sought and collected from the provincial electronic medical database.

Outcomes

The primary outcomes were overall cost and costs for health care services, medical products and lost productive hours in the 6 months following discharge after acute abdominal surgery. Costs were calculated based on a modified version of the self-reported Health Resource Utilization Inventory (HRUI) that has previously been validated with administrative data.\textsuperscript{23} Overall, very few resource utilization surveys are available that have been validated exclusively among elderly patients,\textsuperscript{24} and none are relevant to the present study. The HRUI includes patient-reported utilization of health care services (e.g., readmission, emergency department visits and any interactions with allied health care providers, including physicians, nurses, physical therapists and acupuncturists), medical products used or purchased (e.g., walkers, ostomy supplies, diapers, wheelchairs) and productive hours (i.e., lost wages in paid employment or volunteering) within 6 months after discharge. Eyeglasses, dentures and hearing aids were considered unrelated to surgery; the costs for these were excluded. The cost for medical products and lost productive hours were considered patient-borne costs. Prescription medications for pain or sedation were additionally sought, as these are commonly prescribed upon discharge after surgery, and were considered health care services. We did not assess the cost of inpatient rehabilitation programs or outpatient laboratory tests; these are covered by the single-payer public insurance program in the jurisdiction of the participating sites.

The HRUI was administered by telephone 6 months after discharge. Cost of health care services, including medication, were calculated from reimbursement schemes by the Alberta Aids to Daily Living (AADL) program\textsuperscript{25} or using market rates when required. Cost of physician or dental visits were based on published fee schedules\textsuperscript{26-28} and allied health costs were based on local market rates. Costs for medical products were calculated from government\textsuperscript{15} and commercial sources. Total productive hours lost in paid employment or volunteer positions were multiplied by the mean hourly wage ($\text{CAD}29.27\textsuperscript{29}) in Alberta.\textsuperscript{10} All costs are reported in Canadian dollars ($USD1 = $\text{CAD}1.32) and correspond to January 2016 reimbursement or market rates.

Statistical analysis

We performed descriptive analyses of demographic and clinical data, including $\chi^2$, Fisher exact and $t$ tests. Study sites were compared and pooled for analysis. Clinical characteristics and cost categories were assessed for statistical significance in univariate analyses (Kruskal–Wallis tests for ordinal data, Fisher exact or $\chi^2$ tests for categorical data, and $t$ tests for continuous variables). As cost data were skewed, outcomes were log-transformed. Data distribution was determined by visual inspection. Overall cost, medical product cost and health care services cost were analyzed using a general linear regression model (GLM).\textsuperscript{31} Gaussian distribution was used for overall cost and medical product cost; $\gamma$ distribution was used for health care services cost in the GLM model. Cost for lost productive hours was analyzed using zero-inflated negative binomial (ZINB) regression,\textsuperscript{12-14} which generates 2 separate models and then combines them. A logit model is generated to assess which patients were a “certain zero” (i.e., where there was no chance an individual could experience any cost because they weren’t working or volunteering before admission). Then, a negative binomial model is used to predict the adjusted cost for patients who are not certain zeros (i.e., patients who are not predicted “certain zeros” are included in the nested negative binomial model). Finally, the 2 models are combined. The ZINB model was compared with a traditional negative binomial model using the Vuong test. The GLM and ZINB models report $b$-coefficients for log count of cost. Variables were sequentially added to models and kept if $p < 0.20$. Age and site was forced into each model. To ease interpretation, $b$-coefficients were inversely transformed and can be interpreted as adjusted ratios (AR).

In sensitivity analyses, we considered 6-month readmission in models for medical products and productivity costs, but not elsewhere, as readmission forms part of the dependent variable (health care services utilization). We assessed model fit using the Bayesian information criterion (BIC), which penalizes for additional variables. Lower BIC indicates a more plausible model given the data. Outliers were retained within the models. Health care costs are driven by outliers that represent a disproportionate percentage of overall expenditure. Removing outliers would result in excluding patients who use a sizable portion of the health care budget. Analyses were performed using STATA software version 14 (StataCorp LP). We considered retus to be significant at $p < 0.05$, 2-tailed.

Results

Of the eligible participants ($n = 308$), 66 were unable or unwilling to participate; 242 patients enrolled. Thirteen patients died within 6 months of enrolment, and 79 were lost to follow-up (Fig. 1). Overall, 65.5% of enrolled participants who were alive at 6 months ($n = 150$) completed 6-month assessments (Fig. 1). The median age of patients was of 73.7 (range 65–96.5) years, and 54.1% were men. Nearly all patients (93.9%) were living independently...
before admission and had a median CFS score of 3 (range 1–6); 10.8% had major and 48% had minor complications postoperatively (Table 1). When comparing those who completed the survey and those who were lost to follow-up, there was no difference in age, BMI, sex, marital status, ostomy creation, Charlson Comorbidity Index score, American Society of Anesthesiologists (ASA) classification, preadmission dementia diagnosis, postoperative complications or number of readmissions. Among those who were lost to follow-up, frailty was greater ($p < 0.001$), length of stay was longer ($p = 0.014$), and there were more visible minorities ($p < 0.001$).

The mean 6-month overall cost was $3921 ± $8582 (max: $48 893) and the median was $496 (interquartile range [IQR] $140–$1948; Table 2). After log transformation there was no skewness ($p = 0.13$). Stratified by frailty, patients deemed to be well (CFS = 2), to be managing well (CFS = 3) or to be mildly frail (CFS = 5) had the lowest 6-month overall costs (Table 2). In multivariable analysis, increasing age predicted slightly decreasing overall cost (AR = 0.96, $p = 0.047$), whereas being admitted to the University of Alberta Hospital predicted a 2-fold increase in overall costs (AR 2.14, $p = 0.003$) after controlling for postoperative level of care, frailty, ASA class and comorbidities (Table 3).

In general, health care services accounted for the bulk of postdischarge costs ($138, IQR $65–$332). Log transformation resulted in persistent skewness ($p = 0.003$). Stratified by frailty, costs for health care services were greatest among the moderately frail group (CFS = 6; Table 2). In multivariable analysis, a 1-category increase in frailty independently predicted a 76% increase in health care services costs (AR 1.76, 95% confidence interval [CI] 1.43–2.18, $p < 0.001$) within 6 months of discharge (Table 3).

Most patients did not accrue costs for medical products within 6 months (Table 2). Log-transformed data did not contain skewness ($p = 0.07$). Stratified by frailty, the cost of medical products was highest among moderately frail patients (CFS = 6; Table 2). In multivariable analysis, increases in frailty independently predicted a 61% increase in cost for medical products (AR 1.61, 95% CI 1.15–2.25, $p = 0.006$); marital status, age, ostomy creation or modification, length of stay and site also predicted increased cost (Table 3).

Lost productive hours were analyzed using a ZINB model. The ZINB model fit our data considerably better than a negative binomial model ($p = 0.002$, Vuong test) and the log-transformed data were not skewed ($p = 0.36$) after removing zeros. Most patients (115 of 150) also did not accrue costs for lost productive hours within 6 months (Table 2). Stratified by frailty, lost productivity was predominantly observed in very fit (CFS = 1) or well (CFS = 2) patients, but was also seen in patients managing well (CFS = 3) and in vulnerable patients (CFS = 4; Table 2 and Fig. 2). In the ZINB analysis, a 1-category increase in frailty independently predicted a 2-fold increase in

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**Table 1. Baseline demographic and clinical characteristics of study participants ($n = 150$)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean ± SD, yr</td>
<td>75.5 ± 7.6</td>
</tr>
<tr>
<td>Male sex</td>
<td>81 (54.1)</td>
</tr>
<tr>
<td>Visible minority</td>
<td>18 (12.1)</td>
</tr>
<tr>
<td>Married</td>
<td>113 (75)</td>
</tr>
<tr>
<td>Living independently before admission</td>
<td>141 (93.9)</td>
</tr>
<tr>
<td>Perioperative</td>
<td></td>
</tr>
<tr>
<td>Clinical frailty score, median (range)</td>
<td>3 (1–6)</td>
</tr>
<tr>
<td>BMI, mean ± SD</td>
<td>27.6 ± 5.9</td>
</tr>
<tr>
<td>Charlson Comorbidity Index, mean ± SD</td>
<td>1.0 ± 1.0</td>
</tr>
<tr>
<td>Postoperative recovery on regular ward</td>
<td>134 (89.2)</td>
</tr>
<tr>
<td>ASA ≥ 3</td>
<td>87 (58.1)</td>
</tr>
<tr>
<td>Type of surgery</td>
<td></td>
</tr>
<tr>
<td>Appendix</td>
<td>21 (14.2)</td>
</tr>
<tr>
<td>Gallbladder/biliary tree</td>
<td>39 (25.7)</td>
</tr>
<tr>
<td>Hernia</td>
<td>33 (22.3)</td>
</tr>
<tr>
<td>Intestinal</td>
<td>63 (41.9)</td>
</tr>
<tr>
<td>Stomach or rectum</td>
<td>7 (4.7)</td>
</tr>
<tr>
<td>Other</td>
<td>23 (15.5)</td>
</tr>
<tr>
<td>Ostomy created or revised</td>
<td>16 (10.8)</td>
</tr>
<tr>
<td>Postoperative</td>
<td></td>
</tr>
<tr>
<td>LOS until ready for discharge, mean ± SD</td>
<td>10.3 ± 9.1</td>
</tr>
<tr>
<td>Total LOS, mean ± SD</td>
<td>11.0 ± 10.4</td>
</tr>
<tr>
<td>Minor complication (Clavien–Dindo I–II)</td>
<td>64 (43.2)</td>
</tr>
<tr>
<td>Major complication (Clavien–Dindo III–VI)</td>
<td>16 (10.8)</td>
</tr>
<tr>
<td>No. of readmissions within 6 mo</td>
<td>41 (27.3)</td>
</tr>
</tbody>
</table>

ASA = American Society of Anesthesiologists; BMI = body mass index; LOS = length of stay; SD = standard deviation.

*Unless indicated otherwise.
probability that the patient was not working or volunteer-
ing before admission (AR 2.13, 95% CI 1.38–3.30, \(p = 0.001\); Table 3) and predicted decreased cost for lost pro-
ductive hours for those who were working or volunteering before admission (AR 0.39, 95% CI 0.21–0.71, \(p = 0.002\); Table 3). Male sex also independently predicted a more
than 2-fold increase in lost productive hours (AR 2.28, 95% CI 1.05–4.99, \(p = 0.042\); Table 3) within 6 months of
discharge. Age was associated with more often reporting
no lost productive hours (AR 1.11, 95% CI 1.03–1.19, \(p = 0.004\); Table 3).

### Sensitivity analyses

On additional assessment, all-cause 6-month readmission
independently predicted increased cost for medical prod-
ucts but not for lost productive hours. Inclusion in the
model improved fit (Table 4). Notably, univariate logis-
tic regression of major complications did not identify
significant interactions with overall cost or cost associ-
ated with lost productive hours. It did identify increased
costs for medical products (AR 1.09, \(p = 0.002\)) and
health care services (AR 3.51, \(p = 0.040\)); however, these

### Table 2. System and patient-borne costs within 6 months of discharge, according to frailty (n = 150)*

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Cost, median (IQR), $CAD</th>
<th>Range, $CAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall cost</td>
<td>496 (140–1948)</td>
<td>40–48 893</td>
</tr>
<tr>
<td>Health care</td>
<td></td>
<td></td>
</tr>
<tr>
<td>services</td>
<td>138 (65–332)</td>
<td>0–44 232</td>
</tr>
<tr>
<td>Medical products</td>
<td>0 (0–371)</td>
<td>0–4661</td>
</tr>
<tr>
<td>Lost productivity</td>
<td>0 (0–0)</td>
<td>0–37 100</td>
</tr>
</tbody>
</table>

Table 3. Total and subgroup costs at 6 months after discharge

<table>
<thead>
<tr>
<th>Covariate*</th>
<th>AR (95% CI)</th>
<th>(p) value</th>
<th>BIC†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health care services; generalized linear model ((y) distribution)</td>
<td>0.97 (0.93–1.01)</td>
<td>0.18</td>
<td>–487</td>
</tr>
<tr>
<td>Clinical Frailty Scale score (per 1-pt increase)</td>
<td>1.89 (1.52–2.36)</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>0.58 (0.28–1.18)</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>Medical products; generalized linear model (Gaussian distribution)</td>
<td>1.09 (1.04–1.15)</td>
<td>0.001</td>
<td>110</td>
</tr>
<tr>
<td>Clinical Frailty Scale score (per 1-pt increase)</td>
<td>1.61 (1.15–2.25)</td>
<td>0.006</td>
<td></td>
</tr>
<tr>
<td>Length of stay (per 1-d increase)</td>
<td>1.06 (1.02–1.11)</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>0.35 (0.15–0.83)</td>
<td>0.018</td>
<td></td>
</tr>
<tr>
<td>Ostomy</td>
<td>5.36 (1.47–19.44)</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>Lost productive hours; zero-inflated model (chance patient is certain zero?)</td>
<td>1.11 (1.03–1.19)</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Charlson Comorbidity Index (per 1-pt increase)</td>
<td>0.79 (0.50–1.23)</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>Clinical Frailty Scale score (per 1-pt increase)</td>
<td>2.13 (1.38–3.30)</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Nested negative binomial regression (cost if working before admission)</td>
<td>0.95 (0.88–1.02)</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Clinical Frailty Scale score (per 1-pt increase)</td>
<td>0.39 (0.21–0.71)</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>High-acuity bed postoperatively</td>
<td>2.13 (0.996–4.54)</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Sex, male</td>
<td>2.28 (1.05–4.99)</td>
<td>0.042</td>
<td></td>
</tr>
<tr>
<td>Overall cost; generalized linear model (Gaussian distribution)</td>
<td>0.96 (0.92–0.999)</td>
<td>0.047</td>
<td>–198</td>
</tr>
</tbody>
</table>

AR = adjusted ratio; ASA = American Society of Anesthesiologists; BIC = Bayesian information criterion; CI = confidence interval.
*Age and location were forced into each model.
†Lower BIC values indicate better model fit.
results were not significant in multivariable analysis. Minor complications did not predict a change in any category. The cost of lost productive hours was initially assessed using a multivariable GLM; frailty (AR 1.50, \( p < 0.001 \)) and age (AR 2.47, \( p = 0.009 \)) were significant. However, the fit of the GLM was much worse than that of the ZINB model (BIC = 1006 v. BIC = 1). The ZINB model is also specifically designed to account for data sets with high numbers of zeros and consequently was chosen as the superior model.

![Fig. 2. Overall and subcategory costs according to frailty. Boxes represent the interquartile range (IQR), while whiskers define 1.5 times the IQR. Outliers are indicated by symbols.](image_url)

<table>
<thead>
<tr>
<th>Covariate*</th>
<th>AR (95% CI)</th>
<th>( p ) value</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical products; generalized linear model (Gaussian distribution)</td>
<td>1.09 (1.03–1.15)</td>
<td>0.003</td>
<td>72</td>
</tr>
<tr>
<td>Age (per 1-yr increase)</td>
<td>1.45 (1.03–2.06)</td>
<td>0.036</td>
<td></td>
</tr>
<tr>
<td>Clinical frailty score (per 1-pt increase)</td>
<td>1.07 (1.03–1.12)</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Length of stay (per 1-d increase)</td>
<td>0.35 (0.15–0.84)</td>
<td>0.017</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>3.59 (0.97–13.26)</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Ostomy creation or modification</td>
<td>3.34 (1.36–8.22)</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>Readmitted at least once within 6 mo of discharge</td>
<td>1.11 (1.03–1.19)</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Lost productive hours; zero-inflated model (chance patient is certain zero?)</td>
<td>1.50 (1.03–2.06)</td>
<td>0.003</td>
<td>5</td>
</tr>
<tr>
<td>Age (per 1-yr increase)</td>
<td>0.79 (0.50–1.23)</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>Charlson Comorbidity Index (per 1-pt increase)</td>
<td>2.13 (1.38–3.30)</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Clinical frailty score (per 1-pt increase)</td>
<td>0.94 (0.88–1.01)</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Nested negative binomial regression (cost if working before admission)</td>
<td>0.42 (0.22–0.79)</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>High-acuity bed postoperatively</td>
<td>2.25 (0.99–5.11)</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Readmitted at least once within 6 mo of discharge</td>
<td>0.75 (0.32–1.76)</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>Male sex</td>
<td>2.29 (1.06–4.98)</td>
<td>0.036</td>
<td></td>
</tr>
</tbody>
</table>

AR = adjusted ratio; BIC = Bayesian information criterion; CI = confidence interval.
*Age and location were forced into each model.
†Lower BIC values indicate better model fit.
Owing to the high number of patients with no cost in the medical product cost category, we also performed a ZINB analysis. We felt that GLM regression was a more appropriate analysis of this sort of cost data (all patients could experience this cost), but we wanted to test the robustness of our findings. Increasing frailty remained a significant predictor of cost in those who experienced cost (AR 1.48, 95% CI 1.24–1.77, p < 0.001). Ostomy creation also predicted higher cost (AR 1.95, 95% CI 1.05–3.63, p = 0.035); increasing age (AR 0.97, 95% CI 0.94–0.999, p = 0.042) and male sex (AR 0.62, 95% CI 0.38–0.999, p = 0.05) predicted lower cost. Increasing frailty (AR 0.60, 95% CI 0.43–0.84, p = 0.003) and age (AR 0.92, 95% CI 0.87–0.97, p = 0.002) also predicted a lower probability of experiencing no cost. Overall, the ZINB model fit much worse than the GLM model (BIC = 1268 v. BIC = 110). Length of stay and marital status were not robust, but the effect of frailty and ostomy creation remained large and statistically significant.

When minor or major complications were included in the multivariable GLM regression and ZINB models there was no significant interaction. Major complications were retained only in health care services and remained nonsignificant.

**DISCUSSION**

Elderly surgical patients incur both system and patient-borne costs after discharge. Health care services costs account for the majority of postdischarge costs experienced by patients in our study, as most patients did not experience costs for medical products or lost productivity within 6 months of discharge. The costs experienced by patients following discharge depend on their premorbid health state before surgery and clinical course. Frailty was associated with higher health care services utilization and greater medical product use. Increasing frailty predicted that patients were less likely to be working or volunteering before admission; however, increasing frailty in patients who had been working or volunteering before admission predicted lower cost of lost productive hours. Additionally, in those who were working or volunteering before admission, increasing age was associated with decreased cost from lost productivity. This is likely explained by older or more frail patients working fewer hours per week before admission, which decreases the maximum economic loss they could experience if they were no longer able to work after discharge. This resulted in a nonlinear distribution of cost. Patients with frailty scores of 1 and 6 experienced the highest mean costs.

Cost analysis of postdischarge costs typically account for direct medical costs while ignoring the wider economic impact of recuperation. The only other study to examine postdischarge costs in general surgery patients was conducted in older patients undergoing elective colorectal surgery.\(^{18}\) It showed that increased cost following discharge is associated with increasing frailty, as measured by an unvalidated assessment of frailty domains. The study did not incorporate lost wages, use of complementary health care providers (e.g., massage therapists, chiropractors) or other disposable health care products used.

Overall cost was significantly influenced only by age. A 4% decrease in cost was associated with each year increase in age. This was likely a statistical error, as there was a significant increase in medical product cost (9%) with age and a significant decrease in cost of lost productive hours (5%).

We measured several different sources of cost, which responded to our measured variables in different ways. Some of our measured cost categories increased with increasing frailty (medical products and health care services cost), whereas other measured variables decreased (lost productivity). This results in a nonlinear association between frailty and total cost. Patients who were well (CFS = 1) and those who were frail (CFS = 6) experienced higher cost than those who were in between. This resulted in frailty having no statistically significant influence on overall cost in our linear model and most predictors having no significant effect on overall cost.

Frail patients are more likely to be readmitted to hospital, resulting in increased emergency department utilization, which is included in our health care services cost category. Overall, only frailty predicted increased cost after controlling for age, length of stay and other clinical factors. It predicted a significant increase in the cost of health care services. This is consistent with previous findings. Addressing frailty with targeted interventions may help reduce these costs.

Medical product cost was influenced by several factors. Ostomy creation resulted in a 5-fold increase in patients’ medical product costs. After controlling for frailty, each additional day of admission and each year of life also resulted in significant cost increases. Moreover, in addition to being costly in its own right, hospital readmission may also be a clinically important driver of patient-borne costs, as readmitted patients may require additional medical products or services.

Paid work and volunteering are treated as economically equivalent in economic analysis. As people age they become less likely to work; however, volunteerism among older adults remains quite common. Our analysis found that increasing age and frailty predicted decreased employment or volunteerism before the index admission. Conversely, younger and less frail patients experienced higher costs (up to $37 000) over 6 months. This is because those who worked or volunteered more hours before admission experienced a higher economic loss if they were unable to return to their work or volunteer activities following surgery.

Previous studies have shown significant costs associated with inpatient care following postoperative complications.\(^{16,17}\) However, we did not find a statistically significant
association between major or minor complications in any cost category after controlling for age, frailty and other clinically relevant factors. This may be due to the increased risk of complications associated with increased age and frailty. Adding complications to the model may not add any explanatory power to the model beyond the variables already in the model.

Many of the factors we have identified that influence cost are not modifiable. However, identifying frailty allows for improved assessment and implementation of frailty-specific care plans. The use of comprehensive geriatric assessment (CGA) to evaluate seniors has been shown to improve outcomes in a Cochrane review of acute medical admissions. A systematic review of economic evaluations of CGA in a surgical setting has shown improved outcomes while also reducing cost in patients with hip fracture, and a Cochrane review of CGA in surgical patients is currently underway. We are currently investigating the effect of CGA and an elder-friendly care program in an acute general surgery patient population to see if we can improve outcomes in frail seniors.

Limitations

To our knowledge, this study is the first to examine a range of costs, including lost wages, in elderly patients following discharge after emergency surgery. However, though we conducted in-depth assessment of patient-reported sources of cost after discharge using a validated questionnaire, data collection did not include overnight care in rehabilitation programs or outpatient laboratory tests. Moreover, despite the size of the overall sample, subgroup analyses were limited by small sample sizes, as many patients declined to respond to questionnaires or were unavailable. It is possible that nonresponders included patients with increased frailty and length of stay, who were more likely to be transferred to higher levels of care at much higher cost; this would make follow-up more difficult and would result in our analysis generating conservative estimates for costs. It is also possible that we did not identify any significant effect from complications because those who experienced complications (and consequently had longer lengths of stay) did not answer our questionnaire. We were also unable to assess cost associated with death postdischarge, as our survey was conducted at the final follow-up for the surgery or in patients who were managed conservatively by a surgical team because they did not meet our inclusion criteria. Further microcosted analysis of all enrolled patients is planned when the EASE study is published. Despite collecting and assessing a comprehensive list of clinical and operative variables in-hospital, lower $R^2$ and BIC values suggest that much of the variation between costs results from factors not controlled for in our models. Finally, some of our cost subgroups had only a small number of respondents who experienced a cost. This is commonly seen in cost analysis and has been controlled for within our analysis but does limit the interpretability of our results and may be a source of low $R^2$ in our models.

Conclusion

Understanding predictors and types of cost accrued following surgical discharge in older patients is important to sufficiently address rising health care expenditure and understand the economic impact of surgery in elderly patients. Previous economic models to predict postoperative costs have mostly been unsuccessful. Our findings will be useful to physicians and policy-makers as they consider the financial burden experienced by patients and the attributes associated with higher cost. First, frailty should be considered in prediction models of postdischarge costs. Second, interventions designed to reduce perioperative morbidity, and consequently length of stay and readmission, should consider varying degrees of frailty and consider system costs as well as patient-borne costs among older adults, including lost productivity. Finally, this study highlights a need for further investigation of whether targeted interventions can reduce inpatient and postdischarge costs.

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Competing interests: None declared.

Contributors: G. Eamer, F. Clement, T. Churchill and R. Khadaroo designed the study. G. Eamer and J. Pederson acquired the data, which all authors analyzed. G. Eamer, J. Pederson and R. Khadaroo wrote the article, which all authors reviewed and approved for publication.

References


Effect of patient decision aid was influenced by presurgical evaluation among patients with osteoarthritis of the knee

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Background: Decision aids help patients make total joint arthroplasty decisions, but presurgical evaluation might influence the effects of a decision aid. We compared the effects of a decision aid among patients considering total knee arthroplasty at 2 surgical screening clinics with different evaluation processes.

Methods: We performed a subgroup analysis of a randomized controlled trial. Patients were recruited from 2 surgical screening clinics: an academic clinic providing 20-minute physician consultations and a community clinic providing 45-minute physiotherapist/nurse consultations with education. We compared the effects of decision quality, decisional conflict and surgery rate using Cochran–Mantel–Haenszel $\chi^2$ tests and the Breslow–Day test.

Results: We evaluated 242 patients: 123 from the academic clinic (61 who used the decision aid and 62 controls) and 119 from the community clinic (59 who used the decision aid and 60 controls). Results suggested a between-site difference in the effect of the decision aid on the patients’ decision quality ($p = 0.09$): at the academic site, patients who used the decision aid were more likely to make better-quality decisions than controls (54% v. 35%, $p = 0.044$), but not at the community site (47% v. 51%, $p = 0.71$). Fewer patients who used decision aids at the academic site than at the community site experienced decisional conflict ($p = 0.007$) (33% v. 52%, $p = 0.05$ at the academic site and 40% v. 24%, $p = 0.08$ at the community site). The effect of the decision aid on surgery rates did not differ between sites ($p = 0.65$).

Conclusion: The decision aid had a greater effect at the academic site than at the community site, which provided longer consultations with more verbal education. Hence, decision aids might be of greater value when more extensive total knee arthroplasty presurgical assessment and counselling are either impractical or unavailable.

Contexte : Les aides à la décision guident les patients dans leurs choix quant à l’arthroplastie par prothèse totale, mais l’évaluation préopératoire pourrait modifier leur influence. Nous avons comparé cette influence chez les patients qui envisagent une arthroplastie totale du genou dans 2 cliniques de dépistage chirurgical ayant des processus d’évaluation différents.


Résultats : Nous avons évalué 242 patients : 123 de la clinique universitaire (61 qui ont utilisé l’outil et 62 témoins) et 119 de la clinique communautaire (59 qui ont utilisé l’outil et 60 témoins). Les résultats semblaient indiquer une différence entre les sites quant à l’influence de l’aide sur la qualité des décisions des patients ($p = 0.09$) : au site universitaire, les patients qui l’ont utilisée étaient plus susceptibles de prendre des décisions de qualité que les témoins (54% c. 35%, $p = 0.044$), mais ce n’était pas le cas au site communautaire (47% c. 51%, $p = 0.71$). Moins de patients qui ont utilisé les aides à la décision au site universitaire qu’au site communautaire avaient vécu un conflit décisionnel ($p = 0.007$) (33% c. 52%, $p = 0.05$ au site universitaire; 40% c. 24%, $p = 0.08$ au site communautaire). L’influence de l’outil sur les taux d’intervention chirurgicale était la même aux 2 sites ($p = 0.65$).
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In Canada, patients considering total knee arthroplasty (TKA) have traditionally been referred from primary care directly to an orthopedic surgeon, causing unequal referral distribution and variation in wait times among surgeons. Centralized osteoarthritis (OA) surgical screening clinics were established to improve timely assessment and promote appropriate surgical referrals. Health care professionals assess patients to determine their surgical candidacy, with candidates referred to an orthopedic surgeon and others returned to primary care for conservative management.

Achieving patient-centred care and positive patient experiences requires that decisions are based on informed patients’ preferences. Decision aids are evidence-based clinical tools that help patients reach informed preferences. They provide patient-friendly information about the options, including their benefits and harms, and guide patients in the decision-making process. In Canada and the United States, randomized controlled trials (RCTs) evaluating decision aids for patients considering TKA showed that patients who used decision aids were more knowledgeable, had more realistic expectations, achieved better decision quality (i.e., extent that informed decisions were consistent with patient preferences), were more prepared for the surgical consultation, and had reduced decisional conflict (i.e., uncertainty about the best treatment option). Orthopedic surgeons also reported improved satisfaction and consultation efficiency when their patients were exposed to a decision aid.

A Canadian trial showed that decision aids resulted in lower costs and more quality-adjusted life years for patients considering total joint arthroplasty.

In a larger study, we evaluated a decision aid in 2 clinics using different presurgical evaluation approaches for total joint arthroplasty. At the academic clinic, most patients were scheduled for a 15- to 20-minute presurgical assessment with a sports medicine physician or advanced practice physiotherapist. At the community clinic, patients were scheduled for a 45-minute presurgical assessment with an advanced practice physiotherapist or nurse practitioner. Despite exposure to the same decision aid, we noted discrepancies in findings between the 2 sites, suggesting that the presurgical evaluation influenced the outcomes. With ongoing efforts to implement decision aids in surgical pathways, more knowledge is needed to better understand the circumstances that optimize the use of decision aids.

Therefore, in the present study we compared findings between patients exposed to a TKA decision aid and controls at 2 different surgical screening clinics.

**Conclusion**

L’aide à la décision a eu un plus grand effet au site universitaire qu’au site communautaire, qui offrait de plus longues consultations et plus d’enseignement verbal. Ce type d’outil aurait donc plus de valeur dans les cas où il est difficile ou impossible d’offrir une évaluation préopératoire détaillée et des conseils approfondis pour l’arthroplastie totale du genou.

**METHODS**

**Design**

We conducted a subgroup analysis of a larger prospective 2-site RCT designed to examine the effectiveness of a decision aid compared with standard education for patients considering hip and knee total joint arthroplasty. Our methods are described briefly here, with additional details published elsewhere. Research ethics board approval was obtained at each participating hospital.

**Participants and setting**

Participants were recruited at 2 OA surgical screening clinics in Eastern Ontario, Canada: an academic teaching hospital and a community hospital. In the original RCT, allocations were stratified by site and type of joint needing surgery (i.e., hip or knee). Our subgroup analysis eliminated the hip joint strata owing to the small number of patients undergoing hip surgery at one of the sites. Eligible patients had moderate to severe knee OA. We excluded patients who had inflammatory arthritis, had previous total joint arthroplasty surgical consultation, were unable to read or understand English, or did not have access to a television with a VCR/DVD player to view the decision aid.

At both sites, patients were assessed for surgical candidacy using the 7-item Western Canada Wait List Hip Knee Priority Tool mapped onto 3 guideline criteria indicating those appropriate for TKA (moderate to severe pain, moderate to severe functional limitations, abnormal radiographic findings). Surgical candidates were then scheduled for a consultation with 1 of 7 surgeons at the academic site or 1 of 6 surgeons at the community site.

**Intervention**

Intervention groups were given a decision aid entitled, “Treatment choices for knee OA,” which included a video and booklet (Health Dialog, USA). Patients were instructed to take the decision aid home, review it, and complete study questionnaires to assess their knowledge, values, preferred treatment choice and decisional conflict. These findings, combined with the patients’ clinical data, were summarized in a 1-page report and sent to the surgeon.

All patients (control and intervention) received clinic-specific written information about the prerehabilitation
program and TKA. For the control group participants, surgeons were given a half-page summary of patients’ clinical findings (i.e., Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC] and Hip-Knee Priority Tool scores).

**Outcome measures**

We evaluated the quality of the decisions, decisional conflict, surgery rates and wait times. Quality of the decision was measured as a knowledge test score greater than 66% and whether the patient’s predicted probability of having surgery matched their actual choice. The predicted probability of surgery was calculated using a logistic regression equation derived from items that assessed the patient’s values from the validated Hip and Knee Decision Quality Instrument. Patients who answered “no” to any SURE test item were experiencing decisional conflict. Wait times were calculated as the number of days from the patient’s presurgical screening to the date he/she implemented the OA management decision (i.e., surgery date, date of decision to decline surgery).

**Statistical analysis**

All data were analyzed using SAS software version 9.3. We analyzed wait times using Cox proportional hazards regression with group, site and group × site interaction as independent variables. We compared other outcomes using Cochran–Mantel–Haenszel χ² tests with the Breslow–Day test for examining heterogeneity across sites. Differences in decision with group, site and group × site interaction as independent variables. We compared other outcomes using Cochran–Mantel–Haenszel χ² tests with the Breslow–Day test for examining heterogeneity across sites. Differences in decisional conflict at the academic clinic (13% v. 23%, RR 0.86, 95% CI 0.75–1.00; p = 0.043) but not at the community clinic (18% v. 13%, RR 1.38, 95% CI 0.95–1.96, p = 0.08). At the 6-month follow-up, there was no significant difference in the proportions of participants in the decision aid and control arms who were still experiencing decisional conflict at the academic clinic (13% v. 23%, RR 0.57, 95% CI 0.33–0.94, p = 0.043) but not at the community clinic (18% v. 13%, RR 1.38, 95% CI 0.53–3.59, p = 0.50).

At 2 years, there was no significant difference in the effect of the decision aid on surgery rates between the academic and community sites (p = 0.65). Patients exposed to the decision aid at both sites had lower surgery rates than controls; at the academic site, 73% of patients who used the decision aid had surgery compared with 86% of controls, whereas at the community site, 68% of patients who used the decision aid had surgery compared with 78% of controls. Overall, intervention patients were 14% less likely to have surgery than controls (RR 0.86, 95% CI 0.75–1.00; p = 0.043).

The effect of the decision aid on wait times did not differ significantly between the academic and community sites (p = 0.41). Overall, the decision aid had no statistically significant effect on decisional conflict, surgery rates and wait times.

**RESULTS**

Between May 2008 and October 2009, 242 patients with knee OA were recruited. In this subgroup analysis, 123 were from the academic site (61 who used the decision aid and 62 controls) and 119 were from the community site (59 who used the decision aid and 60 controls). There were no clinically important baseline differences between the decision aid and control groups based on demographic characteristics or OA severity (Table 2).

There was a suggestion of a difference between sites for decision quality (Breslow–Day between sites p = 0.09). At the academic clinic, a significantly higher number of patients in the decision aid arm than the control arm achieved an informed decision based on patient preferences (i.e., decision quality; 54% v. 35%, RR 1.53, 95% CI 1.00–2.33, p = 0.044; Table 3). At the community clinic, there were no significant differences in decision quality between the decision aid and control arms (47% v. 51%, RR 0.93, 95% CI 0.64–1.86, p = 0.71).

There was a significant difference in the effect of the decision aid on decisional conflict between the academic and community sites within 2 weeks (p = 0.007) but not at 6 months (p = 0.19). At the academic clinic, fewer patients who used the decision aid than controls experienced decisional conflict at 2 weeks (33% v. 52%, RR 0.62, 95% CI 0.42–1.00, p = 0.05), whereas at the community clinic, more patients who used the decision aid than controls experienced decisional conflict (40% v. 24%, RR 1.68, 95% CI 0.95–2.96, p = 0.08). At the 6-month follow-up, there was no significant difference in the proportions of participants in the decision aid and control arms who were still experiencing decisional conflict at the academic clinic (13% v. 23%, RR 0.57, 95% CI 0.33–0.94, p = 0.043) but not at the community clinic (18% v. 13%, RR 1.38, 95% CI 0.53–3.59, p = 0.50).

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The effect of the decision aid on wait times did not differ significantly between the academic and community sites (p = 0.41). Overall, the decision aid had no statistically significant effect on decisional conflict, surgery rates and wait times.
significant effect on wait times \( (p = 0.53) \). The median time from referral to removal from the wait list (i.e., date of surgery or date of decision to decline the surgery) at the academic site was 194 days for patients who used the decision aid compared with 195 days for controls \( (p = 0.47) \). At the community clinic, the median wait time was 110 days for patients who used the decision aid compared with 116 days for controls \( (p = 0.23) \).

**Discussion**

We compared decision aid findings for patients considering TKA at 2 centralized surgical screening clinics with different presurgical evaluation processes. We found that the presurgical evaluation influenced the quality of the decision and decisional conflict in patients who received the decision aid. The decision aid reduced the uptake of surgery at both sites and did not impact wait times at either site.

Patients at the academic site who were exposed to the decision aid were 53% more likely to achieve a quality decision than controls, but there was no difference in quality of decisions between the decision aid and control groups at the community site. Additionally, patients who used the decision aid reported less decisional conflict than controls at the academic site, whereas there was no significant difference between the decision aid and control group participants’ decisional conflict at the community site. One potential explanation for these findings is that patients treated at the community site were already highly engaged in the decision-making process (i.e., longer visits with additional verbal counselling), yielding limited additional benefit from the decision aid. Additionally, there was a difference in how patients were counselled during the presurgical evaluation, which might have influenced decision aid findings. We noted that counselling at the community site often included a treatment recommendation, whereas the consultation at the academic site was less directive. In contrast, decision aids engage patients by informing them about options, weighing the risks and benefits, and clarifying their preference. As such, the control group at the community site might have been aware of fewer treatment options. Thus, it was not surprising that decisional conflict increased immediately after patients became informed of the options and subsequently resolved after discussing their preferred option with the surgeon.\(^{16,17}\) Our results showed that decisional conflict decreased for all groups after patients had consulted with their surgeon.

We found that patients given the decision aid were less likely to choose surgery than controls. Decision aids have been shown to moderate unwarranted practice variation by preventing the overuse of options that informed patients do not value, such as invasive elective surgery over more conservative management.\(^{5,18,19}\) A recent RCT found a nonsignificant reduction in the proportion of patients choosing hip or knee arthroplasty after learning about other options described in a decision aid.\(^9\) As the

<table>
<thead>
<tr>
<th>Table 2. Characteristics of included participants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Academic site; mean ± SD</strong></td>
</tr>
<tr>
<td>Characteristic</td>
</tr>
<tr>
<td>--</td>
</tr>
<tr>
<td><strong>Age, yr</strong></td>
</tr>
<tr>
<td><strong>HKPT†</strong></td>
</tr>
<tr>
<td><strong>WOMAC‡</strong></td>
</tr>
<tr>
<td><strong>Sex, male:female</strong></td>
</tr>
<tr>
<td><strong>BMI</strong></td>
</tr>
<tr>
<td><strong>Language, English:other</strong></td>
</tr>
<tr>
<td><strong>Education</strong></td>
</tr>
<tr>
<td>&lt; High school</td>
</tr>
<tr>
<td>High school</td>
</tr>
<tr>
<td>College</td>
</tr>
<tr>
<td>University</td>
</tr>
<tr>
<td>Living arrangements, alone:with someone</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
</tr>
<tr>
<td>Full-time</td>
</tr>
<tr>
<td>Part-time</td>
</tr>
<tr>
<td>Retired</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Household income, ≤ $58 000:more§</td>
</tr>
<tr>
<td>Change in household income, yes:no:no response</td>
</tr>
</tbody>
</table>

BMI = body mass index; HKPT = Hip-Knee Priority Tool; SD = standard deviation; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.

*Unless indicated otherwise.

†Scores range from 0 to 80, without x-rays. Higher scores indicate greater severity of osteoarthritis.

‡Scores range from 0 to 96. Higher scores indicate greater severity of osteoarthritis.

§The typical Canadian household income for adults aged 65 years and older was $58 000 at the time of study recruitment.
uptake of TKA varies significantly among geographical locations, decision aids might help determine the “right rate” of TKA based on patients’ informed preferences.19 Although our original RCT found no overall effect of the decision aid on wait times, patients at the community site waited a median of 20 days less for surgery than controls; there were no differences between groups at the academic site.7 Our subgroup analysis showed no statistically significant differences between academic and community sites for wait times. This suggests that original trial differences in median wait times at the community site are likely accounted for in the hip OA patient sample, which we excluded in this study.

Finally, our findings have important practice implications pertaining to the use of decision aids and cost-effective approaches to involving patients in decision-making. We found that additional decision support strategies, whether intensive counselling or use of a decision aid, benefited patients and decreased surgery rates. Although it is clear that patients value involvement in the decision-making process, selecting the most effective and efficient approach for presurgical evaluation must consider factors that will influence positive patient outcomes. Our study suggests that using the decision aid at the academic site could have compensated for the shorter consultation process, with no difference in outcomes compared with those of patients who received lengthier presurgical evaluations at the community site. Therefore, this shorter presurgical evaluation with a patient decision aid is likely to improve clinical efficiency and surgeon satisfaction, inform and empower patients, and help reduce unwarranted practice variation in surgery rates.5,18,19

**Limitations**

Two important study limitations should be considered. The original sample was powered for the wait time outcome.7 Given that we excluded patients with hip OA (n =

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**Table 3. Outcomes comparing academic and community sites**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Academic site; no. (%)</th>
<th>Community site; no. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Decision aid</td>
<td>Control</td>
</tr>
<tr>
<td>Decision quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Informed values-based choice</td>
<td>30/56 (54)</td>
<td>21/60 (35)</td>
</tr>
<tr>
<td>Knowledge scores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knows pain from hip/knee osteoarthritis gets worse</td>
<td>49/57 (86)</td>
<td>53/60 (88)</td>
</tr>
<tr>
<td>Knows recovery time for most people to get back to usual</td>
<td>5/57 (8)</td>
<td>6/60 (10)</td>
</tr>
<tr>
<td>Knows rates for replacing the same joint in &lt; 15 yr</td>
<td>14/57 (25)</td>
<td>14/60 (23)</td>
</tr>
<tr>
<td>Knows 75% have less pain when walking after surgery</td>
<td>43/57 (75)</td>
<td>34/60 (57)</td>
</tr>
<tr>
<td>Knows rates of serious complication from surgery</td>
<td>42/57 (74)</td>
<td>26/60 (43)</td>
</tr>
<tr>
<td>Patient preferred and actual choice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred</td>
<td>38/57 (67)</td>
<td>45/60 (75)</td>
</tr>
<tr>
<td>Actual</td>
<td>43/59 (73)</td>
<td>53/62 (86)</td>
</tr>
<tr>
<td>Non-surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred</td>
<td>7/57 (12)</td>
<td>4/60 (7)</td>
</tr>
<tr>
<td>Actual</td>
<td>11/59 (19)</td>
<td>8/62 (13)</td>
</tr>
<tr>
<td>Unsure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred</td>
<td>12/57 (21)</td>
<td>11/60 (18)</td>
</tr>
<tr>
<td>Actual</td>
<td>5/59 (9)</td>
<td>1/62 (2)</td>
</tr>
<tr>
<td>Decisional conflict (SURE test)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felt sure about best choice</td>
<td>40/57 (70)</td>
<td>45/60 (75)</td>
</tr>
<tr>
<td>Knew the benefits and harms of each option</td>
<td>51/57 (90)</td>
<td>36/60 (60)</td>
</tr>
<tr>
<td>Was clear about benefits and risks that mattered most</td>
<td>47/57 (83)</td>
<td>39/60 (65)</td>
</tr>
<tr>
<td>Had enough support and advice to make choice</td>
<td>49/57 (86)</td>
<td>41/60 (68)</td>
</tr>
<tr>
<td>Total screened positive for decisional conflict</td>
<td>19/57 (33)</td>
<td>53/60 (82)</td>
</tr>
<tr>
<td>Total screened positive for decisional conflict at 6 mo</td>
<td>6/45 (13)</td>
<td>10/43 (23)</td>
</tr>
</tbody>
</table>
101) from this study, it was likely underpowered for wait time analyses. Additionally, in this study we did not measure or analyze consultations, counselling and/or information exchange between the health care professionals and patients.

**CONCLUSION**

Our findings showed that using different decision support strategies in presurgical evaluation can achieve comparable outcomes. Policy-makers and health care professionals should consider using decision aids with clinical counselling as an alternative to lengthy screening procedures when determining efficient high-quality service delivery models for TKA presurgical screening. Future research involving economic evaluations of patient decision support is required to confirm the most efficient strategy for particular approaches.

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**Competing interests:** G. Dervin is a paid consultant for Stryker and Microport Corporations, advising on total and partial knee replacement. At the time of the study, the informed Medical Decisions Foundation that provided funding for the study had a licensing agreement with Health Dialog, a commercial company who markets decision aids and health coaching. No other competing interests declared.

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**Contributors:** L. Boland and D. Stacey designed the study. D. Stacey acquired the data, which all authors analyzed. L. Boland and L. Trenaman wrote the article, which all authors reviewed and approved for publication.

**References**


Tertiary care centre adherence to unified guidelines for management of periprosthetic joint infections: a gap analysis

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Background: The success rate of surgical treatment for periprosthetic joint infection (PJI) remains inconsistent in the literature. Variability in PJI clinical guidelines and surgeon adherence to guidelines could affect treatment success. The objectives of this study were to appraise current recommendations for PJI management and develop a unified clinical standard of care, to perform a gap analysis of PJI cases in a tertiary institution to determine the rate of guideline adherence, and to determine if adherence to unified PJI guidelines affected 2-year treatment outcomes.

Methods: We appraised the PJI guidelines from 3 academic medical societies, and consistent statements were aggregated. We retrospectively reviewed all PJI cases in a tertiary care institution. We defined PJI based on Musculoskeletal Infection Society PJI criteria. Surgeon adherence to preoperative, intraoperative, surgical and medical management guidelines was calculated, and we evaluated the association between guideline adherence and 2-year treatment outcomes.

Results: The institutional rate of PJI was 1.13% (38 of 3368). Treatment success was 57.8% at 2 years. Unified guideline adherence percentages varied substantially: 92% of patients had preoperative erythrocyte sedimentation rate and C-reactive protein, 97% had intraoperative tissue cultures, 42% had appropriate preoperative arthrocentesis, and 74% underwent guideline-appropriate surgery. Performing appropriate preoperative arthrocentesis significantly correlated with positive treatment outcomes at 2 years ($p = 0.028$).

Conclusion: Adherence to PJI guidelines varies considerably, indicating that clinicians are either unaware of them or do not recognize their value for PJI treatment. This study shows the need for institution-based PJI treatment pathways that are consistent with published guidelines and the need to monitor adherence.

Contexte : Les études ne concordent pas quant au taux de réussite du traitement chirurgical des infections de prothèses articulaires (IPA). Une certaine variabilité dans les lignes directrices sur ces infections et dans l’adhésion des chirurgiens à celles-ci pourrait nuire à la réussite du traitement. La présente étude visait à évaluer les recommandations actuelles sur la prise en charge des IPA afin d’élaborer une norme de soins uniforme, à effectuer une analyse des lacunes entourant les cas d’IPA dans un établissement de soins tertiaires pour déterminer le taux d’adhésion aux lignes directrices, et à déterminer si l’adhésion à des lignes directrices uniformes influençait les issues de traitement après 2 ans.

Méthodes : Nous avons évalué les lignes directrices sur les IPA de 3 sociétés médicales universitaires, et agréé des énoncés cohérents. Nous avons également examiné de façon rétrospective tous les cas d’IPA dans un établissement de soins tertiaires pour déterminer le taux d’adhésion aux lignes directrices, et à déterminer si l’adhésion à des lignes directrices uniformes influençait les issues de traitement après 2 ans.

Résultats : Le taux d’IPA dans l’établissement était de 1,13 % (38 sur 3368), et le taux de réussite du traitement était de 57,8 % après 2 ans. Les pourcentages d’adhésion aux lignes directrices variaient considérablement : 92 % des patients avaient eu une analyse préopératoire de la vitesse de sédimentation érythrocytaire et de la protéine C-réactive, 97 % avaient eu des cultures tissulaires peropératoires, 42 % avaient eu une arthrocentèse préopératoire appropriée, et 74 % avaient subi une intervention chirurgicale conforme aux lignes directrices. Il y avait une corrélation significative entre l’arthrocentèse préopératoire et les issues favorables après 2 ans ($p = 0.028$).

Conclusion : L’adhésion aux lignes directrices sur les IPA varie considérablement, ce qui indique que les chirurgiens ne les connaissent pas ou n’en reconnaissent pas la valeur pour le traitement des IPA. La présente étude montre qu’il faut dans les établissements des protocoles de traitement conformes aux lignes directrices publiées, et qu’il est nécessaire de surveiller l’adhésion des chirurgiens à celles-ci.
Periprosthetic joint infection (PJI) is a devastating complication that can occur following total joint arthroplasty. The treatment of PJI often involves multiple surgical procedures and a prolonged recovery period. Consequently, patients with PJI report greater dissatisfaction and significantly poorer health-related quality of life than patients without PJI. Furthermore, the development of PJI is associated with a dramatically increased risk of death, with reported 5-year mortality ranging from 25.9% to 45%. Although the incidence of PJI following primary joint arthroplasty is commonly reported to be around 1%, recent reports suggest that the incidence of PJI is increasing, with a predicted incidence of 4 million cases per year in the United States by 2030.

This rising incidence coupled with the increasing demand for joint arthroplasty has led to a financial burden for treating PJI that is projected to be in excess of $1.6 billion per year in the United States by 2020.

Despite the rising prevalence and cost associated with PJI, reported treatment outcomes remain inconsistent in the literature. Surgical irrigation and débridement, a recommended treatment for early PJI, has a reported success rate of 8%–71%. Meanwhile, the gold standard treatment for chronic PJI, the “2-stage” revision arthroplasty, has a reported failure rate of 5%–23%. This variability in treatment efficacy makes clinical decision-making difficult for the treating physician, who wishes to balance the morbidity of invasive surgery with the probability of treatment success. Proper prognosticating treatment success is further compounded when the diagnosis of PJI is not straightforward, such as in the setting of culture-negative PJI or infection due to Propionibacterium acnes.

In response to challenges with the diagnosis and treatment of PJI, several medical associations have developed evidence-based clinical practice guidelines over the last decade. Although such guidelines were established to help standardize PJI management, to date no assessment of congruity among these guidelines or physician adherence to them in clinical practice has been performed. Exploring guideline heterogeneity and variation in physician practices could help explain local variation in PJI outcomes and identify opportunities to improve outcomes through standardization of both diagnostic and management strategies.

The objectives of the present study were to appraise the current literature recommendations for PJI diagnosis and management and organize them into a unified PJI clinical standard of care, to perform a gap analysis of qualifying PJI cases in a tertiary institution to quantify the rate of guideline adherence by treating surgeons, and to report if any association between guideline adherence and treatment outcome was observed. To our knowledge, no previous studies have examined institutional adherence rates for PJI management.

Methods

We obtained institutional review board approval before study commencement.

Currently, there are a variety of clinical practice guidelines available for the diagnosis and management of PJI. These guidelines have been developed by groups of clinicians who rigorously reviewed the literature and achieved agreement in working groups using accepted consensus-building techniques. To develop a unified clinical standard of care for which PJI management in our institution could be compared, we reviewed the clinical practice guidelines produced by 3 major academic societies: the American Academy of Orthopaedic Surgeons (AAOS), the Infectious Disease Society of North America (IDSNA) and the Musculoskeletal Infection Society (MSIS). Clinical practice guidelines that received a “strong” recommendation from both the AAOS and IDSNA were incorporated into the current clinical standard of PJI management. Two clinicians experienced in PJI management (A.C. and H.A.) independently reviewed the 207 consensus statements outlined in the 2014 MSIS international consensus proceedings and identified statements that were identical to or consistent with AAOS/IDSNA “strong” recommendations or those that involved direct recommendations for how to diagnose and manage PJI and were supported by at least 85% of participating MSIS members. The resulting consensus statements and clinical practice guidelines agreed upon by the 2 reviewers were collapsed into a unified clinical standard of care.

All primary total knee (TKA), hip (THA) and shoulder (TSA) arthroplasty procedures performed at a tertiary referral centre between Jan. 1, 2011, and Dec. 31, 2013, were retrospectively reviewed. The centre performs an average of 1400 primary joint replacement surgeries per year and has on-call access to arthroplasty-specialized surgeons. To identify patients with PJI, we used a 2-step search process. First, the digital charts and laboratory values of all patients were screened to identify patients with 1 or more of the following results: elevated erythrocyte sedimentation rate (ESR), elevated C-reactive protein (CRP), positive joint fluid culture, positive joint tissue culture, surgical reoperation for any reason, and/or an ICD-9 diagnostic code of PJI. Second, one of us (M.D.A.) manually reviewed the electronic and physical charts from all patients with 1 or more positive findings from the first screening. Patients were identified as having PJI if they had either a final ICD-9 diagnosis of PJI or fulfilled MSIS criteria for PJI and had at least a 2-year follow-up.

We collected the following data on patients with PJI: age, sex, body mass index, smoking status, American Society of Anesthesiologists (ASA) classification, Charlson Comorbidity Index score and interval between initial arthroplasty and onset of PJI. We then categorized PJI as early, delayed or late according to the Zimmerli/Trampuz classification. Furthermore, we recorded details regarding the method of PJI workup (radiography, blood tests, aspiration/biopsy, etc.), and treatment outcome was evaluated according to the Zimmerli/Trampuz classification. The rate of guideline adherence by treating surgeons and any association between guideline adherence and treatment outcome was observed. To our knowledge, no previous studies have examined institutional adherence rates for PJI management.
number of intraoperative cultures, gram stain), culture results, PJI treatment (antibiotic suppression, irrigation and débridement, 1-stage revision, 2-stage revision, type of antibiotics spacer), antibiotic duration and criteria for proceeding to a second stage revision. The initial data collection was verified by a second reviewer for accuracy.

Treatment success was defined as cessation of antibiotic therapy with a prosthesis or antibiotic spacer implanted, normalized laboratory markers, and no further infectious symptoms for a period of at least 2 years following surgery. After the first surgical treatment and conclusion of antibiotic therapy, we considered treatment to have failed if patients required subsequent surgery and/or acute or chronic antibiotic therapy.

Upon collection of the aforementioned variables, we performed a gap analysis,20 whereby we compared the management of previous PJI cases (actual clinical performance) with a conceptually desired performance (unified clinical standard). This form of analysis has been used previously to evaluate medical institutional performance21 and improve dissemination of best health care practices across institutions.22 For each PJI case, specific features of the preoperative PJI workup, intraoperative workup and surgical treatment, and postoperative PJI management were compared with recommendations from the unified clinical standard to determine the rate of physician adherence. We tabulated the number of guideline statements fulfilled for each case. Owing to the use of an ordinal rank scale (no. of guidelines followed out of a possible 11), we calculated a Spearman correlational coefficient to determine if a significant association existed between guideline adherence and clinical treatment success. We conducted \( \chi^2 \) tests to assess fulfillment of specific guidelines and determine if any of these were significantly more prevalent in cases of successful (i.e., no recurrence of PJI 2 yr after initial treatment) or unsuccessful PJI treatment. All statistical tests assumed 95% confidence intervals (CIs), and we considered results to be significant at \( p < 0.05 \).

RESULTS

We identified 7 “strong” recommendations from the AAOS guidelines and 8 “level A” recommendations identified from IDSNA guidelines. Twelve consensus statements from the MSIS met selection criteria and were incorporated into 10 recommendations, making up the unified clinical standard for diagnosis and management of PJI (Box 1).

Over the 3-year study period, a total of 3368 primary THAs, 19 (1.3%) had TKAs and 2 (2.02%) had TSAs.

Of the 38 cases of PJI, 22 (57.8%) met criteria for successful treatment (Table 2) after a single surgical procedure at an average follow-up of 2.11 (range 2.0–3.4) years. The 16 patients in whom initial management failed underwent an average of 2.9 ± 1.24 surgical procedures in total. After 2 years (Table 3), 3 of these 16 patients had undergone multiple irrigation and débridements, with no infectious symptoms at the most recent follow-up. Eight patients had undergone at least 1 implant revision and had no infectious symptoms at the most recent follow-up.

**Box 1. Unified periprosthetic joint infections (PJI) guidelines**

**Preoperative evaluation (performed before the initiation of oral or intravenous antibiotic treatment)**

1. Serum erythrocyte sedimentation rate/C-reactive protein
2. Anteroposterior and lateral radiographs of the affected joint
3. Diagnostic arthrocentesis with fluid sent for the following:
   a. Cell count and differential
   b. Culture and sensitivity

**Intraoperative evaluation and management**

1. Intraoperative collection of at least 3 tissue cultures
2. Débridement with exchange of modular components and implant retention is indicated if:
   a. PJI diagnosed within 30 days of the index arthroplasty procedure
   b. PJI diagnosed within 3 weeks of symptoms
3. A revision arthroplasty (1-stage/2-stage) with implant removal is indicated if:
   a. PJI is diagnosed after 30 days since the index arthroplasty procedure and/or symptoms have been greater than 3 weeks.
   b. PJI has recurred following previous débridement and modular component exchange.
4. Resection arthroplasty and/or chronic antibiotic suppression is indicated for PJI recurrence following multiple 1-stage/2-stage surgery failures.

**Medical management**

1. Empiric, broad-spectrum antibiotics are administered immediately after surgical management and continued until final culture results are obtained.
2. Following débridement and implant retention, treatment consists of pathogen-specific intravenous antibiotics for 2–6 weeks in combination with rifampin.
3. Following resection arthroplasty or 1-stage/2-stage revision arthroplasty, treatment consists of pathogen-specific intravenous antibiotics for 2–6 weeks in combination with rifampin.
4. For chronic suppression of PJI, pathogen-specific antibiotics are administered (orally or intravenously) for at least 3 months.

**Table 1. Demographic and clinical characteristics of study participants (n = 38)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean [range], or no. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>68.5 [27–85]</td>
</tr>
<tr>
<td>BMI</td>
<td>30.8 [19.4–54.4]</td>
</tr>
<tr>
<td>American Society of Anesthesiology classification</td>
<td>2.8 [2–4]</td>
</tr>
<tr>
<td>Charlson Comorbidity Index score</td>
<td>3.5 [1–7]</td>
</tr>
<tr>
<td>Sex, male:female</td>
<td>16:22</td>
</tr>
<tr>
<td>Smoker</td>
<td>6 (15)</td>
</tr>
<tr>
<td>Concurrent/recurrent infection</td>
<td>4 (10)</td>
</tr>
<tr>
<td>Immunocompromised</td>
<td>8 (20)</td>
</tr>
<tr>
<td>Drug resistant bacteria</td>
<td>15 (39.5)</td>
</tr>
<tr>
<td>BMI = body mass index.</td>
<td></td>
</tr>
</tbody>
</table>

*Unless indicated otherwise.*
symptoms at the most recent follow-up. Three patients were placed on long-term oral antibiotic suppression, 1 patient underwent implant resection and arthrodesis, and 1 patient died within 2 years of the initial surgery.

**Gap analysis**

For the preoperative workup for PJI, 33 (86.4%) patients had serum ESR and CRP levels measured, 20 (52.6%) had joint-specific plain radiographs completed, and 25 (65.8%) underwent diagnostic arthrocentesis (Fig. 1). Of the cases with completed arthrocentesis, only 16 (64%) included a cell count, manual differential and bacterial culture.

With respect to intraoperative diagnosis and management, intraoperative culture and gram stains were acquired in 100% of cases. Specifically, fluid cultures were obtained in 92.1% of cases and tissue cultures were obtained in 97.4%. Only 42.1% of cases had 3 or more tissue cultures acquired at the time of surgery. For operative management, irrigation with débridement and modular component...
exchange was the most common procedure performed, occurring in 28 (73.7%) patients with a success rate of 64.2%. For 10 of the 38 (26.3%) patients with PJI, the operative procedure performed was not consistent with the unified PJI guidelines. In 9 of these patients, irrigation with débridement and modular component exchange was performed instead of implant revision.

With respect to postoperative medical management, consultation with infectious disease specialists occurred in 35 (92.1%) cases. Organism-specific intravenous antibiotics were administered for at least 4–6 weeks in 37 (97.3%) patients.

Association between guideline adherence and treatment outcome

Of the 4 preoperative measures identified in the unified guidelines, an average of 2.23 ± 0.97 were completed, with 4 cases achieving all 4 measures and 9 cases achieving only 1 measure (serum CRP and ESR levels). For treatment success, performing a diagnostic arthrocentesis and appropriately ascertaining cell count and bacterial culture was significantly correlated with a positive PJI treatment outcome at 2 years (Spearman correlation coefficient = 0.357, \( p = 0.028 \)). Undergoing a diagnostic arthrocentesis significantly correlated with better preoperative guideline adherence (ESR/CRP, radiographs, diagnostic arthrocentesis and antibiotics withheld; Spearman correlation coefficient = 0.722, \( p < 0.001 \)), but was otherwise not associated with any other treatment variable.

For intraoperative culture requirements or surgical management, only 14 of 38 cases (36.8%) fulfilled both requirements according to the unified guidelines. In 8 cases (21.1%), neither the correct number of cultures nor appropriate surgical management were performed. No significant correlations were found for fulfilling culture requirements, appropriate use of irrigation and débridement or appropriate surgical management with overall PJI treatment outcome. Furthermore, postoperative infectious disease consultation and use of antibiotics was not correlated with PJI treatment outcome. A complete list of variables and correlational coefficients is provided in Table 4.

Overall, of the 8 PJI management guidelines, an average of 5.3 ± 1.27 (range 3–8) were followed per case. There was no significant correlation between overall PJI guideline adherence rate and treatment outcomes. The timing of PJI (early/delayed/late) was significantly associated with the surgical procedure chosen (Spearman correlation coefficient = −0.642, \( p < 0.001 \)), with the negative number reflecting the large number of irrigation and débridesments performed. Body mass index, history of diabetes, smoking and Charlson Comorbidity Index score did not correlate with PJI treatment outcomes.

Discussion

To our knowledge, this study is the first to compare and unify current PJI guidelines and then investigate how often orthopedic surgeons adhere to these guidelines when managing PJI. Although involving only a single tertiary care institution, the study results are generalizable, given that the PJI rate of 1.13% following primary arthroplasty is similar to the rates reported in the literature, as is the 63% treatment success with irrigation and débridement. Furthermore, the management of patients with PJI was not limited to arthroplasty surgeons, but rather consisted of a multispecialty group, further increasing the generalizability of the results. In this reported series of 38 cases, we identified great variability in the way surgeons diagnose and manage PJI. Although 92% of patients with suspected PJI did undergo initial serological screening and 100% were treated with some form of operative management, the inconsistent use of diagnostic modalities and surgical procedures suggest that orthopedic surgeons do not recognize their value or are conflicted regarding the various PJI guidelines currently available. We advocate that the development of a simple,
A unified set of clinical practice guidelines published under the collective banner of both orthopedic and infectious disease societies would substantially improve and clarify how best to diagnose and manage PJI. Application of this unified guideline within an institution could then reduce treatment inconsistencies and optimize outcomes.

Limitations

We acknowledge several limitations to this study. First, we recognize that the diagnosis and management of PJI is complex, and that the unified guidelines proposed in this study do not cover all diagnostic tests, do not evaluate criteria for 1-stage versus 2-stage revision and instead simplify the subtypes of surgical management. However, these guidelines were created using objective, unbiased criteria that identified the strongest recommendations from 3 of the largest academic bodies to guide PJI care. We decided to reconcile these strong recommendations to avoid preferential treatment to 1 specific academic body and to quantify physician adherence to clinical rules that are generally known among orthopedic surgeons. A second limitation is the relatively small number of PJI cases included and the even smaller number of cases that underwent initial full implant revision, which limits the statistical power of the study. Such small numbers are explained by the stringent criteria for study inclusion: specifically, meeting MSIS criteria and a minimum 2-year follow-up in order to define treatment success consistent with recommendations in the literature. A final limitation is that we were unable to explicitly retrieve reasons for why surgeons did or did not follow PJI guidelines for each case. Although presenting symptoms (draining sinus, septic shock, previous history of PJI) and surgeon expertise (fellowship-trained or not) are observable factors that could affect diagnostic and surgical management, other influences, such as diagnostic test availability, access to the operating room, physician attitudes toward the effectiveness of PJI guidelines and physician-specific differences in technique (method of arthrocentesis, quality of surgical débridement, amount of irrigation used), are not easy to collect in a retrospective fashion. Moving forward, we plan to engage these surgeons in reviewing the current guidelines, promote comparative data-sharing and evaluate how patient-based and facility-based factors affect PJI care as part of our continuous quality improvement initiatives. Such efforts have been shown to improve physician guideline adherence and encourage the building of multidisciplinary teams within single institutions.29-31

Despite not being properly performed in more than half of the cases in our series, a preoperative diagnostic arthrocentesis is an important tool in the management of PJI. Although the precise technique of arthrocentesis has been scrutinized in the recent PJI literature, its use has been described as mandatory in the context of chronic PJI, as bacterial identification can help determine if a 1-stage or 2-stage revision is indicated.32-34 Yet, apart from sending aspirated fluid for culture, the PJI literature offers a wide array of other assays to diagnose PJI. Although synovial leukocyte counts and neutrophil percentages are widely recommended for PJI diagnosis, the thresholds vary according to the type of joint infected, acute versus chronic infection, and infection of a primary versus a revised joint. Synovial CRP and a variety of inflammatory cytokines have been lauded as being superior to serum testing, but these tests are not widely available, they are expensive, and they are not consistently reproduced.35-37 For our study series, the use of preoperative arthrocentesis with both culture and leukocyte count thresholds to diagnose PJI, it is logical to assume that arthrocentesis-based bacterial culture permits proper identification of the offending organism and permits expedient perioperative use of appropriate antibiotics, which can eradicate infection. Choosing the appropriate surgical management is the next step.

Irrigation, débridement and modular component exchange was the most common surgical protocol used in our series; with a 64% success rate it is an appealing, yet somewhat controversial treatment for PJI. In addition to being technically easier than a full implant revision, the procedure can be better tolerated by a large percentage of patients with PJI, who are generally fragile and have multiple comorbidities. The above features as well as the observation that patients with PJI operated on by nonarthroplasty surgeons were included in the study series could explain why irrigation and débridement was the most common surgical procedure performed. Unfortunately, the contemporary outcomes for irrigation and débridement in patients with PJI vary substantially in the literature, with 2-year cure rates ranging from 29% to 92%.38-41 Furthermore, results from several large case series suggest that a failed irrigation and débridement is associated with even poorer outcomes following a subsequent 2-stage revision. In the last 2 years, very poor results, even in the context of acute infection, have led several PJI experts to recommend against the routine use of irrigation and débridement, with the sole exception being a specifically immunologically competent patient who has a non-Staphylococcal, low-virulence infection.42-44 Although our correlational findings suggest that surgeons factor in the timing of PJI with the type of surgical procedure offered, further investigations are needed to determine what patient and institutional factors influence surgeons to perform irrigation and débridement as well as what, if any, intraoperative techniques influence the outcome of the procedure.
CONCLUSION

The present investigation suggests that unified, simplified PJI guidelines and efforts to improve adherence to such guidelines are seriously needed. Although previous efforts to improve guideline adherence among orthopedic surgeons have not always been successful, the rising incidence and dramatic care costs associated with PJI mandate an earnest effort at both the institutional and national levels. It is hoped that these efforts as well as published attempts for consensus among experts will help clarify what features of PJI diagnosis and management are the most effective.

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Competing interests: None declared.

Contributors: All authors designed the study. M. Armstrong acquired and analyzed the data, which A. Carli, H. Abdelbary, S. Poitras and P. Beaulé also analyzed. M. Armstrong, A. Carli and P. Beaulé wrote the article, which all authors reviewed and approved for publication.

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*Based on page views on PubMed Central of research, reviews, commentaries and discussions in surgery. Updated Jan. 16, 2018.
Physical performance following acute high-risk abdominal surgery: a prospective cohort study

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Line Toft Tengberg, PhD
Thomas Bandholm, PhD
Nicolai Bang Foss, DMSc
Morten Tange Kristensen, PhD

Presented in part at the Danish Surgical Society’s annual meeting, November 2014, Frederiksberg, Denmark; at the congress of the Danish Physical Therapy Association, March 2015, Odense, Denmark; and at Hvidovre Hospital researcher’s day, April 2015, Hvidovre, Denmark.

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Background: Acute high-risk abdominal (AHA) surgery is associated with high mortality, multiple postoperative complications and prolonged hospital stay. Further development of strategies for enhanced recovery programs following AHA surgery is needed. The aim of this study was to describe physical performance and barriers to independent mobilization among patients who received AHA surgery (postoperative days [POD] 1–7).

Methods: Patients undergoing AHA surgery were consecutively enrolled from a university hospital in Denmark. In the first postoperative week, all patients were evaluated daily with regards to physical performance, using the Cumulated Ambulation Score (CAS; 0–6 points) to assess basic mobility and the activPAL monitor to assess the 24-hour physical activity level. We recorded barriers to independent mobilization.

Results: Fifty patients undergoing AHA surgery (mean age 61.4 ± 17.2 years) were included. Seven patients died within the first postoperative week, and 15 of 43 (35%) patients were still not independently mobilized (CAS < 6) on POD-7, which was associated with pulmonary complications developing (53% v. 14% in those with CAS = 6, \( p = 0.012 \)). The patients lay or sat for a median of 23.4 hours daily during the first week after AHA surgery, and the main barriers to independent mobilization were fatigue and abdominal pain.

Conclusion: Patients who receive AHA surgery have very limited physical performance in the first postoperative week. Barriers to independent mobilization are primarily fatigue and abdominal pain. Further studies investigating strategies for early mobilization and barriers to mobilization in the immediate postoperative period after AHA surgery are needed.
Acute high-risk abdominal (AHA) surgery is associated with high mortality, multiple postoperative complications and prolonged hospital stay, especially in elderly patients.\(^1\)–\(^6\) It is defined as immediate emergency laparoscopy or laparotomy primarily to treat intestinal obstruction, perforated viscus or bowel ischemia.\(^7\) A focus on enhanced recovery programs specifically for patients following AHA surgery is needed to improve the postoperative outcome.\(^6\)–\(^7\) Possible interventions include reducing time before surgery, the early use of antibiotics, optimized fluid management, pain treatment, early nutrition and early mobilization.\(^8\),\(^10\),\(^12\)

Early mobilization and exercise are known to play important roles in postoperative care following abdominal surgery and are associated with less postoperative reduction of fitness and fewer postoperative complications in patients undergoing elective surgery.\(^9\),\(^11\)–\(^20\)

There are, to our knowledge, no published data on postoperative physical performance, level of 24-hour physical activity, or barriers to independent mobilization within the first week following AHA surgery. Such findings are crucial when organizing strategies for enhanced recovery programs after AHA surgery.

The aim of the present study was to describe physical performance and barriers to independent mobilization (on postoperative days [POD] 1–7) in patients who underwent AHA surgery.

**METHODS**

**Study population**

This single-centre prospective cohort study included consecutive patients who underwent AHA surgery between April 27 and June 18, 2014, at the Copenhagen University Hospital, in Hvidovre, Denmark. This study is an embedded part of a larger cohort study, initiated in 2013, investigating the effect of an enhanced recovery program after AHA surgery in 600 patients (Clinicaltrials.gov: NCT01899885).\(^7\) The larger study does not include the aim and outcomes reported in the present study.

The key elements of the enhanced recovery program include the use of a preoperative nasogastric tube, an arterial catheter and antibiotics, surgery within 6 hours after decision to operate, perioperative fluid and pain management (thoracic epidural with local anesthetics and oral nonsteroidal anti-inflammatory drugs [NSAIDs]), and early nutrition and mobilization.\(^7\) In addition to early mobilization, every patient received daily physiotherapy until POD-7 and was evaluated by an occupational therapist. The physiotherapy sessions (10–30 min per session based on the capability of the patient) progressed on an individual level and consisted of exercises in bed and practicing basic mobility activities, including transfer in and out of bed, sitting to standing from a chair, walking and stair climbing. Additionally, walking aids were changed to less supportive aids as needed, as described by Münter and colleagues\(^21\) in a similar study of patients with hip fracture. The goal of physiotherapy was for the patients to achieve independent mobility. When independent, patients were instructed in self-training and the importance of daily and frequent physical activity. If required (e.g., because of shallow breathing, coughing, secretion and atelectasis), patients received specific respiratory therapy on a daily basis.

To be included in the study, patients had to be 18 years or older and undergoing emergency laparotomy or laparoscopy (including reoperations after elective surgery) for intestinal obstruction, perforated viscus or bowel ischemia.\(^7\) Patient characteristics and information about comorbidities; day of admission; type and duration of operation; presence of epidural, preoperative sepsis and postoperative pulmonary complications; Eastern Cooperative Oncology Group (ECOG) scores; American Society of Anesthesiologists (ASA) classification; and 30-day mortality were all extracted from a central database from the larger cohort study. Postoperative pulmonary complications were defined as Clavien–Dindo classification higher than grade I, and preoperative sepsis was evaluated using the predisposition, insult, response, organ dysfunction (PIRO) classification.\(^22\),\(^23\) The ECOG score is a preoperative physical performance status on general well-being and activities of daily living, with a score of 0 indicating perfect health and a score of 5 indicating death.\(^24\) The ASA classification assesses physical status before surgery, with a score of 1 indicating normal health and a score of 5 indicating a moribund patient.\(^25\) The prehospital functional performance, assessed using the New Mobility Score (NMS), was obtained from the electronic patient records supplemented with information from the patient and/or relatives when necessary. The NMS, developed in 1993, is used to assess the functional level in patients with decreased mobility.\(^26\) It assesses 3 activities: walking indoors, walking outdoors and shopping. Each activity is scored from 0 to 3 (0 = not at all able, 1 = able with help from another person, 2 = able with a walking aid, 3 = no...
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difficulty and no aid), giving a total score of 0–9 for overall mobility.27,28

The regional ethical committee waived the need for written informed consent in this study (H-2–2014-FSP31). This study was preregistered with Clinicaltrials.gov: NCT02124356. We used the Strengthening The Reporting of OBServational Studies in Epidemiology (STROBE) checklist for observational studies for the reporting of the study.29

Physical performance

We assessed postoperative physical performance using the Cumulated Ambulation Score (CAS) and with a 24-hour activity monitor (activPAL, PAL Technologies Ltd.).

The CAS was first described in a 2006 validation paper to investigate independence in ambulation following hip fracture surgery.30 In 2012, the CAS was validated for use in geriatric patients.31 Three basic mobility activities are evaluated:

• getting in and out of bed (from supine in bed to sitting at the side of the bed to standing or transfer to sitting in chair placed beside the bed, and return to the supine position in bed)
• sitting to standing to sitting from a chair with armrests
• indoor walking, with an appropriate aid allowed in transfer and walking if necessary

Each activity is scored from 0 to 2 (0 = not able despite human assistance and verbal cueing, 1 = able with verbal cueing and/or human assistance from 1 or more individuals, 2 = able safely without human assistance or verbal cueing), making up a total score of 0–6 reflecting the scale from bedbound to independent mobilization.32,33 In addition to routine treatment, a physiotherapist tested the patients after AHA surgery using CAS on PODs 1–7. A total of 8 skilled physiotherapists participated in data collection. They all had experience using the CAS and were calibrated before the present study.

The 24-hour physical activity level was assessed on PODs 1–8 using the activPAL. The activPAL is a uniaxial accelerometer that registers time spent, in hours, in sitting/lying and standing/walking positions. It also includes an inclinometer that can register the number of transitions made from sitting to standing and from standing to sitting.34,35 The validity of the activPAL has been confirmed in both healthy and hospitalized elderly people.36,37 The monitor was attached to the skin on the anterior of the mid thigh. Every day, a physiotherapist checked the battery and recording indicator and ensured that the monitor was firmly attached. ActivPAL results are presented for PODs 2, 4 and 7 in order to present a picture of the 24-hour activity level immediately after surgery, midweek and 1 week postoperatively. Results from PODs 1 and 8 were omitted because the monitor could not record the full 24-hour period for these days. The decision to omit these data was made during data quality checks before any statistical analyses were run. Results are presented as time (hours) each day spent inactive (sitting/lying) and active (standing/walking) in addition to the number of transitions from sitting to standing. The categories of walking and standing were combined because the activPAL sensor has been known to underestimate the time spent walking at low walking speed.36,37

Barriers to independent mobilization

Patients with a CAS score of 6 are by definition independently mobile with or without a walking aid, thus, we used a CAS score of 6 as a cut-off point for independently/nonindependently mobile patients during hospitalization. Every day, patients who were not independently mobile were asked what factors/barriers had restricted their mobilization, and the physiotherapists registered the primary barrier for independent mobilization from a predefined list: pain, motor blockade, dizziness, exhaustion/fatigue, nausea and vomiting, acute cognitive dysfunction, respiratory problems, unconsciousness, patient declines, logistics (e.g., examination at other hospital ward), monitoring equipment, or other. The list of barriers was predefined by the research group before study initiation.

Pain was assessed using a visual analogue scale (VAS) on PODs 1–7. Patients were asked to indicate their level of pain at rest and during physical activity on a 10 cm line indicating “no pain” to “worst possible pain.” The physiotherapist registered the corresponding measurement on the back of the VAS scale and noted the location of the pain.36,39

Statistical analysis

No previous data existed in this patient group from which a sample size could be made. No formal sample size estimation was done for this descriptive study, but we considered a consecutive sample of 50 patients undergoing AHA surgery to be representative.

Data were tested for normal distribution using the Kolmogorov–Smirnov test and visual inspection of Q–Q plots. For descriptive data, continuous, normally distributed data are presented as means ± standard deviations (SD), categorical and non-normally distributed data are presented as medians and interquartile ranges (IQR), and nominal data are presented as numbers and percentages. We analyzed differences between groups using the independent t test for continuous, normally distributed data, the Mann–Whitney U test for non-normally distributed data and the χ2 or Fisher exact test for categorical and nominal data. We used univariable logistic regression to evaluate the association between the development of a pulmonary complication and the CAS level at POD-7. All analyses were performed using SPSS software version 19. We considered results to be significant at p < 0.05.
RESULTS

Study population

Fifty-three patients underwent AHA surgery during the study period and were eligible for inclusion. Three patients were excluded: 1 because of competing orthopedic surgery on PODs 1 and 2 because they were permanently transferred to another hospital on POD-2 (Fig. 1). The total number of included patients was 50. Missing data in the first postoperative week are clarified in Figure 1.

Patient characteristics are presented in Table 1. The mean age of patients was 61.4 ± 17.2 years, and almost all patients were admitted from their own homes and with a high preoperative functional level. Furthermore, most patients were generally healthy, with a high physical status before surgery when evaluated with the ECOG score (74% had a score of 0–1) and ASA classification (66% were ASA class 1–2). The median length of stay of the cohort was 12 (IQR 7–22) days from the day of AHA surgery to discharge. Ten patients were admitted to the intensive care unit postoperatively for a median of 3.0 (IQR 1.0–5.5) days. During hospitalization, 17 (34%) patients experienced a pulmonary complication within a mean of 3.3 ± 2.5 days after surgery.

Seven patients died and 12 were discharged during the first postoperative week. From PODs 8 to 30, no more patients died. The patients who died were older (mean age 79.7 ± 5.5 yr v. 58.4 ± 16.6 yr, \( p = 0.002 \)) and had a lower median NMS score (5 [IQR 1–5] v. 9 [IQR 9–9], \( p < 0.001 \)) than the rest of the cohort. There was no significant difference in sex distribution between those who died and those who survived (\( p = 0.24 \)), but the 7 patients who died had significantly higher ECOG (≥2) and ASA (5 of 7 patients had ASA ≥3) scores. Five of the 7 patients who died experienced a postoperative pulmonary complication.

Physical performance

During PODs 1–7, 28 of the 43 (65%) patients who survived became independently mobile (CAS = 6) after a median of 3 (IQR 1–8) days. Patients who were non-independently mobile (CAS < 6) on POD-7 were significantly older, were more often admitted to the ICU, more often experienced a pulmonary complication, and had a longer stay in hospital after surgery than those who were independently mobile (Table 2). Correspondingly, the odds of a pulmonary complication occurring in the independent (CAS = 6) group was 85% less (odds ratio 0.15, 95% confidence interval [CI] 0.03–0.63).

The patients lay or sat for a median of 23.8 (IQR 22.8–24.0) hours on POD-2, 23.5 (IQR 22.5–24.0) hours on POD-4, and 23.4 (IQR 22.3–23.8) hours on POD-7. Patients who were independently mobile on different postoperative days stood or walked significantly more minutes, and had more transitions from sitting to standing than those who were not independent (Table 3).

Barriers to independent mobilization

Patients who were not independently mobile on POD-1 were primarily restricted by monitoring equipment (12 of 38) and fatigue (11 of 38). On PODs 2–7 the primary barriers to independent mobilization were fatigue (11 of 38) and monitoring equipment (12 of 38).
barrier to mobilization was fatigue (42%–70%), followed by pain (13%–20%; Table 4). On POD-1, 11 of 42 (26%) patients experienced moderate to severe pain (VAS 5–10), primarily in the abdominal area; the degree and location of pain are presented in Table 5.

**Discussion**

The main findings of the present study were the low level of physical performance in the first postoperative week in patients undergoing AHA surgery despite early mobilization in addition to standardized physiotherapy, occupational therapy assessments and training. Patients who were nonindependently mobile within the first postoperative week more often experienced a pulmonary complication than patients who were independently mobile. The primary barriers to independent mobilization within the first week were fatigue and abdominal pain.

**Physical performance**

Most patients undergoing AHA surgery in this study had a high preoperative functional level and were generally healthy. Thus, a relatively high level of physical performance could be expected after surgery, but this was not the case, as 35% of the patients were nonindependently mobile and had low levels of 24-hour physical activity 1 week after surgery. The remaining patients, although independently mobile, still stood or walked for fewer than 1.5 hours per day in the first postoperative week. This degree of inactivity is associated with a high risk of sarcopenia, loss of muscle strength and decreased functional performance due to immobilization.\(^7\)

Other studies have also reported a low degree of mobilization following abdominal surgery.\(^\text{19,45}\) In the study by Haines and colleagues,\(^\text{19}\) only 48% of patients undergoing abdominal surgery were able to walk more than 10 m away from the bed on POD-1.\(^\text{19}\) Their study included both emergent (22%) and elective surgery (78%) patients, and the primary surgeries were hepatobiliary (60%) and colorectal (31%).\(^\text{19}\) A study by Browning and colleagues\(^\text{45}\) including patients undergoing elective upper abdominal surgery also reported a low level of physical activity within the first 4 days.\(^\text{41}\)

Correspondingly, a recent study by Bailey and colleagues\(^\text{48}\) found that 22.6% of older people (≥70 yr) undergoing nonelective abdominal surgery experienced a loss of independence, and this was associated with increased health care cost. Our results show that patients who were nonindependently mobile 1 week postoperatively were significantly older, more inactive and had an increased risk of longer hospital stay. These results confirm that, following AHA surgery, elderly people are vulnerable and at risk of losing physical performance when hospitalized. Furthermore, the loss of physical performance after discharge in elderly patients is associated with an increased risk of falls, readmission, social isolation, home care replacement and, in the worst case scenario, death.\(^\text{40,41,43,47–49}\) Therefore, intervention strategies, such as early mobilization and more intensive mobilization, should be prioritized for elderly patients. A recent systematic review by Castelino and colleagues\(^\text{16}\) reports little available evidence to guide clinicians in strategies of early mobilization following abdominal and thoracic surgery. This reveals the need for studies investigating the effect of early and standardized mobilization in patients following AHA surgery in association with physical performance.

Among the most frequent postoperative complications following major abdominal surgery are pulmonary complications,\(^\text{17,18}\) which are associated with a low degree of

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**Table 1. Characteristics of patients undergoing AHA surgery (n = 50)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean ± SD, yr</td>
<td>61.4 ± 17.2</td>
</tr>
<tr>
<td>Female sex</td>
<td>24 (48)</td>
</tr>
<tr>
<td>BMI, mean ± SD [range]†</td>
<td>25.0 ± 5.6 [15.3–40.6]</td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
</tr>
<tr>
<td>Obstruction</td>
<td>15 (30)</td>
</tr>
<tr>
<td>Perforation</td>
<td>25 (50)</td>
</tr>
<tr>
<td>Other†</td>
<td>10 (20)</td>
</tr>
<tr>
<td>Type of surgery</td>
<td></td>
</tr>
<tr>
<td>Emergency laparotomy</td>
<td>42 (84)</td>
</tr>
<tr>
<td>Emergency laparoscopy</td>
<td>8 (16)</td>
</tr>
<tr>
<td>Duration of surgery, mean ± SD, h</td>
<td>2.1 ± 1.3</td>
</tr>
<tr>
<td>Thoracic epidural</td>
<td>45 (90)</td>
</tr>
<tr>
<td>Preoperative sepsis§</td>
<td>26 (54)</td>
</tr>
<tr>
<td>Postoperative pulmonary complications</td>
<td>17 (34)</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
</tr>
<tr>
<td>Cardiovascular diseases</td>
<td>22 (44)</td>
</tr>
<tr>
<td>Respiratory diseases</td>
<td>9 (18)</td>
</tr>
<tr>
<td>Diabetes mellitus (type 1 and 2)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>ECOG score</td>
<td></td>
</tr>
<tr>
<td>0–1 points</td>
<td>37 (74)</td>
</tr>
<tr>
<td>2–4 points</td>
<td>13 (26)</td>
</tr>
<tr>
<td>ASA classification</td>
<td></td>
</tr>
<tr>
<td>1–2</td>
<td>33 (66)</td>
</tr>
<tr>
<td>3–4</td>
<td>17 (34)</td>
</tr>
<tr>
<td>LOS after surgery, median (IQR), d§</td>
<td>12 (7–22)</td>
</tr>
<tr>
<td>Admitted to ICU</td>
<td>10 (20)</td>
</tr>
<tr>
<td>LOS in the ICU, median (IQR), d</td>
<td>3.0 (1.0–5.5)</td>
</tr>
<tr>
<td>Residential status, own home</td>
<td>47 (94)</td>
</tr>
<tr>
<td>NMS score, median (IQR)</td>
<td>9 (6–9)</td>
</tr>
<tr>
<td>Walking aid†</td>
<td>11 (22)</td>
</tr>
<tr>
<td>Home care</td>
<td>11 (22)</td>
</tr>
</tbody>
</table>

AHA = acute high-risk abdominal; ASA = American Society of Anesthesiologists; BMI = body mass index; ECOG = Eastern Cooperative Oncology Group; ICU = intensive care unit; IQR = interquartile range; LOS = length of stay in hospital; NMS = New Mobility Score; SD = standard deviation.

*Unless indicated otherwise.

\(\text{IQR} = 48\).  
\(\text{IQR} = 43\).
physical activity and delayed or dependence in mobilization. In the present study 34% of patients experienced postoperative pulmonary complications, which corresponds to the 36% reported for the total cohort of 600 patients who received AHA surgery following a multidisciplinary perioperative protocol. Results of the present study showed that a higher proportion of patients who were nonindependently mobile on POD-7 experienced a pulmonary complication. Nonindependent patients were also more sedentary (lay or sat more) than patients who were independently mobile on POD-7. Evidence suggests that early mobilization may reduce the incidence of pulmonary complications after abdominal surgery, but there is limited knowledge on the frequency and intensity of mobilization needed to achieve this outcome. This reveals the importance of interventions aimed at reducing the risk of postoperative pulmonary complications, where early mobilization and respiratory therapy could play a role.

**Barriers to independent mobilization**

On POD-1, patients and hospital staff reported monitoring equipment (e.g., blood pressure, heart rate, saturation) and therapeutic equipment (e.g., oxygen tubing and intravenous therapy) as the main barrier to mobilization, preventing movement out of the bed in the early stage. In the study by Haines and colleagues, hypotension was the most common barrier to mobilization on POD-1 after acute and elective major abdominal surgery. Hypotension was not by itself an indication for nonindependent mobilization in the present study, and dizziness, which could be a result of orthostatic hypotension, was seldom reported on POD-1.

Throughout PODs 2–7, fatigue was the main barrier to independent mobilization, especially on POD-4 (70%), but it was not possible to explain the reason for patients feeling fatigued based on the data collected in the present study. Fatigue is pronounced after major abdominal surgery, probably because of inflammatory response.

Despite a multimodal analgesia regime, including thoracic epidural with local anesthetics and oral NSAIDs, a large proportion of patients experienced moderate to severe pain in the abdominal area during mobilization. Thus, 13%–20% of the patients reported pain as the main barrier to independent mobilization on PODs 2–7. Correspondingly, other studies found that patients reporting more pain or inadequate pain relief were less physically active after elective abdominal surgery. Overall, fatigue and abdominal pain are the primary barriers to independent mobilization and may inhibit early ambulation, therefore a focus on these barriers and interventions aiming to deal with them, should be considered. Possible interventions are the use of intraoperative high-dose glucocorticoids, which attenuate inflammatory response and could reduce both fatigue and pain, as well as the use of psychotropic drugs that reduce fatigue.

**Limitations**

A limitation to the present study might be that, even though all the included patients attempted mobilization on POD-1, it was not possible to

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**Table 2. Differences in patient characteristics between independently (CAS = 6) and nonindependently (CAS < 6) mobile patients within the first postoperative week (n = 43)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Group: no. (%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean ± SD, yr</td>
<td>CAS &lt; 6 (n = 15)</td>
<td>CAS = 6 (n = 28)</td>
</tr>
<tr>
<td>NMS score, median (IQR)</td>
<td>9 (4–9)</td>
<td>9 (9–9)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>6 (40)</td>
<td>13 (46)</td>
</tr>
<tr>
<td>Male</td>
<td>9 (60)</td>
<td>15 (54)</td>
</tr>
<tr>
<td>Admitted to ICU</td>
<td>6 (40)</td>
<td>1 (4)</td>
</tr>
<tr>
<td>Type of surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergency laparotomy</td>
<td>13 (87)</td>
<td>22 (79)</td>
</tr>
<tr>
<td>Emergency laparoscopy</td>
<td>2 (13)</td>
<td>6 (21)</td>
</tr>
<tr>
<td>Duration of surgery, mean ± SD, h</td>
<td>2.2 ± 1.5</td>
<td>2.0 ± 1.3</td>
</tr>
<tr>
<td>Preoperative sepsis</td>
<td>8 (57)†</td>
<td>15 (56)‡</td>
</tr>
<tr>
<td>Postoperative pulmonary complication</td>
<td>8 (53)</td>
<td>4 (14)</td>
</tr>
<tr>
<td>LOS, median (IQR), d</td>
<td>22 (13–28)</td>
<td>8 (5–14.5)</td>
</tr>
</tbody>
</table>

CAS = Cumulated Ambulation Score; ICU = intensive care unit; IQR = interquartile range; LOS = length of stay; NMS = New Mobility Score; SD = standard deviation. *Unless indicated otherwise.

**Table 3. Level of 24-hour physical activity between independently (CAS = 6) and nonindependently (CAS < 6) mobile patients within the first postoperative week**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Median (IQR)</th>
<th>n*</th>
<th>Median (IQR)</th>
<th>n*</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit/lie, h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POD-2</td>
<td>23.9 (23.8–24.0)</td>
<td>28</td>
<td>22.5 (22.3–23.3)</td>
<td>16</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>POD-4</td>
<td>24.0 (23.7–24.0)</td>
<td>21</td>
<td>22.7 (21.2–23.2)</td>
<td>22</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>POD-7</td>
<td>23.8 (23.5–24.5)</td>
<td>15</td>
<td>22.5 (21.6–23.2)</td>
<td>15</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Stand/steps, h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>POD-2</td>
<td>0.1 (0.0–0.2)</td>
<td>28</td>
<td>1.5 (0.8–1.7)</td>
<td>16</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>POD-4</td>
<td>0.0 (0.0–0.3)</td>
<td>21</td>
<td>1.3 (0.8–2.8)</td>
<td>22</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>POD-7</td>
<td>0.2 (0.1–0.5)</td>
<td>15</td>
<td>1.5 (0.8–2.4)</td>
<td>15</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

CAS = Cumulated Ambulation Score; IQR = interquartile range; POD = postoperative day.

*Number of patients still alive and not discharged.
AHA surgery, further studies investigating strategies for early mobilization and barriers to mobilization in the immediate postoperative period are urgently needed.

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Competing interests: None declared.

Contributors: L.R. Jønsson, L.T. Tengberg, T. Bandholm, N.B. Foss and M.T. Kristensen designed the study. L.R. Jønsson, L.H. Ingelrud and L.T. Tengberg acquired the data, which L.R. Jønsson, L.H. Ingelrud and M.T. Kristensen analyzed. L.R. Jønsson and L.H. Ingelrud wrote the article, which all authors reviewed and approved for publication.

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Comparing the anterior, posterior and lateral approach: gait analysis in total hip arthroplasty

**Background:** The choice of surgical approach for total hip arthroplasty (THA) remains a contentious issue with regards to clinical outcome optimization and restoring patient function. The purpose of this study was to determine the impact of surgical approach for THA on quantitative gait analysis.

**Methods:** Patients undergoing THA for primary osteoarthritis of the hip were assigned to 1 of 3 surgical approaches: anterior, posterior and lateral. Standardized implants were used at the time of surgery. Three-dimensional gait analysis was performed preoperatively and at 6 and 12 weeks postoperatively. At each time point, we compared temporal parameters, kinematics and kinetics.

**Results:** We included 30 patients in our analysis (10 anterior, 10 posterior, and 10 lateral). The groups were similar with respect to age ($p = 0.27$), body mass index ($p = 0.16$), and Charlson Comorbidity Index score ($p = 0.66$). Temporal parameters were similar among the groups at all time points. The lateral cohort had higher pelvic tilt during stance on the affected leg than the anterior cohort at 6 weeks ($p = 0.041$). Affected leg ipsilateral trunk lean during stance was higher in the lateral group than in the other cohorts at 6 weeks ($p = 0.008$) and 12 weeks ($p = 0.040$). The anterior and posterior groups showed increased external rotation at 6 weeks ($p = 0.003$) and 12 weeks ($p = 0.012$) compared with the lateral group.

**Conclusion:** Temporal gait parameters were similar following THA for all approaches. Differences in gait kinematics and kinetics exist; however, given the small absolute differences, the clinical importance of these changes remains undetermined.

**Contexte** : Le choix de l’approche chirurgicale pour la pose d’une prothèse totale de la hanche (PTH) ne fait pas l’unanimité sur le plan de l’optimisation des résultats cliniques et du rétablissement fonctionnel des patients. Le but de cette étude était de déterminer l’incidence de l’approche choisie sur les résultats de l’analyse quantitative de la démarche.

**Méthodes** : Les patients qui se font poser une PTH en raison d’une arthrose primaire de la hanche ont été opérés selon l’une des 3 approches suivantes : antérieure, postérieure ou latérale. Des implants standards ont été utilisés pour la chirurgie. Une analyse tridimensionnelle de la démarche a été effectuée avant l’intervention, puis après 6 et 12 semaines. À chaque étape, nous avons comparé les paramètres temporels, cinématiques et cinétiques.

**Résultats** : Nous avons inclus 30 patients dans notre analyse, soit 10 par approche. Les groupes présentaient des caractéristiques similaires en ce qui concerne l’âge ($p = 0.27$), l’indice de masse corporelle ($p = 0.16$) et l’indice de comorbidité de Charlson ($p = 0.66$). Les paramètres temporels étaient similaires d’un groupe à l’autre à toutes les étapes de l’étude. Six semaines après l’intervention, le groupe opéré selon l’approche latérale présentait une bascule pelvienne à la station debout du côté du membre affecté plus prononcée que le groupe opéré selon l’approche antérieure ($p = 0.041$). Il présentait aussi une inclinaison du tronc du côté de la jambe affectée à la station debout plus marquée que les 2 autres groupes, à 6 semaines ($p = 0.008$) et à 12 semaines ($p = 0.040$). Les groupes opérés selon les approches antérieure et postérieure présentaient une rotation externe accrue à 6 semaines ($p = 0.003$) et à 12 semaines ($p = 0.012$) comparativement au groupe soumis à l’approche latérale.
Total hip arthroplasty (THA) is the hallmark treatment modality for severe arthritis of the hip. The procedure provides excellent patient-reported outcomes and pain mitigation, and is cost-effective when compared with nonoperative care. However, it is important for surgeons and patients to understand the quantitative, biomechanical changes that occur following reconstructive procedures, such as THA. A useful instrument to capture these changes is gait analysis. Validated and reproducible, gait analysis has been used extensively to detect changes in gait mechanics that occur following THA.

There is ongoing interest on the impact of various surgical approaches to the hip for THA gait mechanics. Commonly used surgical approaches for THA include the lateral, posterior and anterior approaches. In Canada, approximately 60% of surgeons use a lateral hip approach, 34% a posterior hip approach and fewer than 5% an anterior approach. The lateral approach involves surgical release and repair of the abductor musculature. The potential functional implications of violating the abductors is unclear but may negatively impact gait mechanics, including a Trendelenburg gait or a compensatory contralateral pelvic tilt. Conversely, the posterior approach involves release and repair of the short external rotators, which can result in changes to rotatory kinetics. Finally, the anterior approach uses an internervous plane between sartorius and tensor fascia latae that attempts to spare the surrounding hip musculature. The presumed advantage of this approach is avoiding the aforementioned deficits seen with the lateral and posterior approaches. However, cadaveric studies have suggested that abductor muscle damage is observed during a THA using an anterior approach, and surgical releases (i.e., piriformis, tensor fascia latae) are sometimes required to improve exposure during preparation of the femur and acetabulum.

Previous studies have elucidated differences in gait analysis between the surgical approaches. Limitations in study design that hamper the ability to interpret those results include retrospective analyses, lack of standardized implants, small sample sizes and heterogeneity in time points used for follow-up.

The purpose of the present study was to determine the impact of surgical approach on gait mechanics following THA. We were particularly interested in the effect of approach on postoperative pelvic tilt and abductor function, as it was unclear whether there is a quantifiable change in these gait parameters following THA. Our hypothesis was that there would be no significant differences in temporal distance, kinematic, or kinetic parameters following THA between the 3 different surgical approaches at early follow-up.

Materials

Patients were distributed through our institution’s centralized arthroplasty intake system and then recruited from the clinic of 1 of 3 fellowship-trained arthroplasty surgeons. Patients were included in the study if they had primary osteoarthritis of the hip; consented for treatment with a THA through an anterior, posterior, or lateral approach; were 19 years of age or older; and did not meet any of the exclusion criteria. The exclusion criteria were body mass index (BMI) greater than 40; diagnosis other than primary osteoarthritis, dementia, or other cognitive disorders; prior hip surgery; cemented THA; simultaneous bilateral THA; cases performed by trainees; use of implants other than those standardized for the study; inadequate understanding of the English language; and inability to complete the gait analysis testing.

We recorded patient demographic characteristics, including age, sex, BMI and age-adjusted Charlson Comorbidity Index score. Each patient was assigned a Charnley class based on history, clinical examination and radiographic images.

Our institutional review board approved our study protocol before we began enrolling patients in the study.

Procedure

Each of the 3 surgeons performed only 1 of the 3 surgical approaches (anterior, posterior, or lateral). Each surgeon had completed more than 100 cases using their respective approach during the course of their training and clinical practice. A specialized operating room table (Hana fracture table, Mizuho OSI) with intraoperative fluoroscopy was used for the anterior approach. The posterior and lateral approaches were performed on a conventional operating room table with the patient in the lateral decubitus position. The posterior approach was completed with an anatomic repair of the short external rotators and joint capsule to the greater trochanter. The lateral approach was performed based on the technique described by Hardinge. A detailed outline of the surgical technique we use for each approach has been published previously. Each patient received standardized implants at the time of the procedure: a hydroxyapatite-coated, cementless femoral stem (Coral stem, DePuy Orthopaedics Inc.), a cementless acetabular cup (Pinnacle Sector II acetabular cup, DePuy Orthopaedics Inc.), a highly cross-linked polyethylene liner (AltrX polyethylene liner, DePuy Orthopaedics Inc.), and a cobalt chrome femoral head (Articul/eze cobalt chrome, DePuy Orthopaedics Inc.). Cancellable screws...
(DePuy Orthopaedics Inc.) were inserted to augment acetabular fixation at the surgeon’s discretion. Postoperatively, all patients received 24 hours of antibiotics. Prophylaxis against deep vein thrombosis was administered. Analgesia was managed by our institution’s acute pain service. All patients were permitted to weight-bear as tolerated and use a gait aid as needed under the guidance of physiotherapy. Patients were discharged once they met the criteria of our institution’s discharge pathway. Outpatient physical therapy was prescribed at the discretion of the surgeon based on patients’ progress.

**Gait analysis**

Patients underwent 3-dimensional gait analysis preoperatively and at 6 and 12 weeks following THA. Twenty-two reflective markers from a modified Helen Hayes marker set were placed on each patient. In addition, we placed 4 markers bilaterally over the medial knee joint line and medial malleolus during an initial static standing trial. Body mass, marker orientation and positions of joint centres of rotation for the knee and ankle were determined. We had the patients complete 2 additional dynamic trials of straight leg swing to determine hip joint centres of rotation. We removed the 4 additional markers before having the patient walk.

Patients then walked across an 8 m walkway at their own pace, without walking aids. All gait analyses were conducted barefoot to negate the potentially confounding effect of shoe type on walking biomechanics. Participants completed a minimum of 12 walking trials to allow for at least 6 clean force plate strikes for each lower limb. We subsequently analyzed 5 trials per limb.

We used an 11-camera, high-resolution motion capture system (Motion Analysis Corporation) operating at 60 Hz to capture temporal distance parameters (gait velocity, step length, stride length) and joint kinematics (hip joint angles, pelvic tilt, lateral trunk lean). A floor-embedded force platform (Model A-6–7, Advanced Mechanical Technology Incorporated) recorded ground reaction forces at 600 Hz, allowing for the calculation of centre of pressure and joint kinetics. External moments about the hip were calculated using inverse dynamics (Orthotrak 6.61, Motion Analysis Corporation). Temporal distance measures, peak hip joint angles, contralateral pelvic tilt, ipsilateral trunk lean and joint moments were compared among the groups.

**Statistical analysis**

Our sample size determination was based on results published by Varin and colleagues, who reported an effect size of 1.25 for postoperative contralateral pelvic tilt comparing the anterior and lateral approach. Using an effect size of 1.2, α of 0.05 and power of 0.80, we determined that 10 patients were required in each group.

We assessed demographic characteristics using descriptive statistics, including frequencies, means and standard deviations. Categorical variables were tested using cross-tabulation with the Pearson χ² test. Variables from the gait analysis were tested for significance using parametric analysis of variance (ANOVA) or nonparametric (Kruskal-Wallis) testing, depending on the distribution of the variable. We performed post hoc testing using a Scheffé test or Mann-Whitney U test when appropriate. We considered results to be statistically significant at p < 0.05. We used SPSS software version 23 (SPSS Inc.) for all analyses.

**RESULTS**

A total of 67 patients were approached for study involvement to acquire the necessary 10 patients per surgical approach. All cohorts had complete preoperative, 6- and 12-week gait analyses (Fig. 1). There were no significant differences in patient demographic characteristics between the groups (Table 1).

There were no significant differences in temporal distance parameters between the groups at any of the time points (Table 2). All groups experienced significant improvements in step length, stride length and gait velocity following THA.

Contralateral pelvic tilt was significantly greater in the lateral than in the anterior cohort at 6 weeks postoperatively (p = 0.041). This finding was no longer significant at 12 weeks. Preoperatively, there was a significant difference in ipsilateral trunk lean between the anterior and posterior approach groups (p = 0.022). However, there was no significant trunk lean difference between these 2 cohorts at 6 or 12 weeks postoperatively. Conversely, the anterior approach group showed significantly less ipsilateral trunk lean than the lateral approach group at 6 weeks (p = 0.008) and 12 weeks (p = 0.040) postoperatively (Table 3). Other significant findings included an increased peak abduction angle in the lateral versus the anterior approach group at 6 weeks (p = 0.021) and differences in peak internal rotation (p = 0.024) and external rotation (p = 0.020) angles between the anterior and lateral cohorts at 12 weeks (Table 4).

**DISCUSSION**

The findings in our study reject our hypothesis that there would be no significant differences in gait parameters following THA between the anterior, posterior and lateral approaches. Although temporal parameters were similar at all time points, there were kinematic and kinetic group differences. These statistical differences may be explained by anatomic aberrancies caused by the surgical approaches, but the clinical relevance of the differences is unknown.

Our study was powered to show a difference in contralateral pelvic tilt. This variable is important for a number of reasons. Lateral trunk lean and resulting pelvic tilt may
help reduce the external knee adduction moment to offload painful medial compartment knee arthrosis.\textsuperscript{13,14} Lateral trunk lean also reduces the joint reaction forces observed by the hip joint with abductor muscle weakness, potentially reducing pain in the presence of hip arthrosis.\textsuperscript{15,16} However, Nankaku and colleagues\textsuperscript{17} showed that with increasing lateral trunk displacement following THA, gait efficiency declines. Takacs and colleagues\textsuperscript{18} also showed that with increasing pelvic tilt, energy expenditure increases. With the aging population, more patients are living with multiple comorbid conditions, such as chronic obstructive pulmonary disease, cardiac disease and renal disease. These comorbidities reduce the capacity of patients to carry out simple activities of daily living (ADL). Therefore, any increase in energy expenditure may reduce independence with ADLs, making subtle changes to pelvic tilt a clinically relevant problem.

Surprisingly, we did not find any difference in peak abduction moments across the cohorts at any time point. As the lateral approach group showed increased pelvic tilt and trunk lean, we expected either an increase in the abductor moment in order to reduce pelvic tilt and trunk lean, or a decrease in the abductor moment due to muscle damage at the time of surgery. As alluded to earlier, it may be that the groups are reducing the abductor moment at the hip to compensate for painful arthrosis at other joints (i.e., medial compartment of the knee). Howell and colleagues\textsuperscript{19} suggested that 16\%–20\% of patients undergoing THA had evidence of abductor mechanism tears. Therefore, it is possible that there are patients in the anterior and posterior cohorts who had abductor insufficiency, thereby making differences between the groups undetectable. This may also explain why there were preoperative differences in trunk lean and peak abduction angle between the groups.

Another significant difference observed between the groups postoperatively was an increased external rotation moment in the anterior and posterior cohorts compared with the lateral approach group. The short external rotators

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**Fig. 1.** Flow of patients through the study. BMI = body mass index.
are incised during a posterior approach, and are often released to improve femoral exposure during an anterior approach to the hip.\textsuperscript{5,11} The increased external rotation moment may be a compensatory mechanism for the damaged muscles. The gluteus medius and maximus are powerful external rotators during early stance.\textsuperscript{20} Recruiting these muscles would prevent internal rotation of the hip, which has a deleterious effect on patello-femoral mechanics of the knee.\textsuperscript{21} Alternatively, the gluteus medius is damaged during a lateral approach to the hip. As mentioned previously, this muscle is a powerful external rotator of the hip. Therefore, damage sustained during surgical dissection could cause a decrease in external rotation moments of the hip until the muscle has healed.

**Limitations**

Our study has limitations. The lack of true randomization may have introduced selection bias on behalf of the surgeon and expectation bias on behalf of the patient. Studies have shown that patients believe minimizing muscle damage is important after major reconstructive surgery, such as THA. Therefore, knowing that an approach potentially is “muscle-sparing” may psychologically prime an individual to be more motivated to achieve earlier mobilization and hasten progress with rehabilitation.\textsuperscript{22} It is important to consider this confounding factor across all comparative studies that examine minimally invasive or muscle-sparing, techniques. The addition of an age-, sex- and

### Table 1. Patient demographic and clinical characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Group; mean [range] or no.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
</tr>
<tr>
<td>Age, yr</td>
<td>70.5 [62–82]</td>
</tr>
<tr>
<td>Sex, female:male</td>
<td>6:4</td>
</tr>
<tr>
<td>BMI</td>
<td>25.6 [20.0–34.1]</td>
</tr>
<tr>
<td>Age-adjusted Charlson Comorbidity Index score</td>
<td>3.6 [1–6]</td>
</tr>
<tr>
<td>Charnley classification</td>
<td>A 1</td>
</tr>
<tr>
<td></td>
<td>B1 5</td>
</tr>
<tr>
<td></td>
<td>B2 3</td>
</tr>
<tr>
<td></td>
<td>C 1</td>
</tr>
</tbody>
</table>

BMI = body mass index.

### Table 2. Summary of temporal distance parameters of gait

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group; mean [range]</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
<td>Posterior</td>
</tr>
<tr>
<td>Step length, m</td>
<td>0.44 [0.25–0.59]</td>
<td>0.53 [0.35–0.67]</td>
</tr>
<tr>
<td>6 wk</td>
<td>0.51 [0.32–0.62]</td>
<td>0.58 [0.51–0.69]</td>
</tr>
<tr>
<td>12 wk</td>
<td>0.52 [0.35–0.63]</td>
<td>0.60 [0.53–0.71]</td>
</tr>
<tr>
<td>Stride length, m</td>
<td>0.86 [0.47–1.13]</td>
<td>1.06 [0.83–1.29]</td>
</tr>
<tr>
<td>6 wk</td>
<td>1.00 [0.58–1.22]</td>
<td>1.14 [0.99–1.36]</td>
</tr>
<tr>
<td>12 wk</td>
<td>1.02 [0.62–1.26]</td>
<td>1.20 [1.11–1.37]</td>
</tr>
<tr>
<td>Gait velocity, m/s</td>
<td>0.67 [0.30–1.08]</td>
<td>0.86 [0.53–1.06]</td>
</tr>
<tr>
<td>6 wk</td>
<td>0.86 [0.50–1.29]</td>
<td>0.98 [0.75–1.15]</td>
</tr>
<tr>
<td>12 wk</td>
<td>0.92 [0.41–1.56]</td>
<td>1.09 [0.99–1.33]</td>
</tr>
<tr>
<td>Stance phase, %</td>
<td>65.0 [59.6–71.0]</td>
<td>62.8 [59.5–64.7]</td>
</tr>
<tr>
<td>6 wk</td>
<td>64.8 [62.5–68.6]</td>
<td>62.9 [59.5–65.4]</td>
</tr>
<tr>
<td>12 wk</td>
<td>64.6 [61.5–70.5]</td>
<td>62.4 [58.6–66.8]</td>
</tr>
<tr>
<td>Swing phase, %</td>
<td>35.0 [29.0–40.5]</td>
<td>37.2 [35.3–40.5]</td>
</tr>
<tr>
<td>6 wk</td>
<td>35.2 [31.4–37.5]</td>
<td>37.1 [34.6–40.5]</td>
</tr>
<tr>
<td>12 wk</td>
<td>35.4 [29.5–38.5]</td>
<td>37.6 [33.2–41.4]</td>
</tr>
</tbody>
</table>

*According to one-way analysis of variance.
BMI-matched control group would provide useful information to understanding how well each surgical approach restores gait mechanics. In addition, randomization may have reduced preoperative kinematic and kinetic differences between the cohorts, although these variables are likely more a function of individual differences than sample selection. We did not report changes in leg length and femoral offset following THA, which could affect gait mechanics by changing the length of the muscles around the hip joint. Our findings are limited to a short-term follow-up of 12 weeks, which may be too short a duration in which to observe optimal restoration of gait mechanics in all groups. Finally, our single-centre study design limits the generalizability of the data, as only 3 surgeons performed the procedures.

Despite these limitations, our study has several strengths. It is a prospective study powered to answer a clinically relevant question: Can gait abnormalities following THA be explained by surgical approach? We also compared the 3 most common surgical approaches used for THA, providing useful information for surgeons. Standardization of the implants used at the time of surgery is important. Controlling for this variable helps minimize the influence of implant specifications, such as neck length (femoral offset and leg length) and mode of biologic fixation (proximal versus distal), that may produce biomechanical changes and affect gait postoperatively. The modified Helen Hayes marker set system has been validated for gait analysis, and we took great care to identify the hip joint centre before testing to account for inaccuracy that can occur with varying body habitus. Finally, each approach was performed by a single surgeon, which strengthens the internal validity of the study.

**CONCLUSION**

The choice of surgical approach for THA remains a contentious issue. Our study shows that although temporal parameters improve regardless of surgical approach, gait kinematic and kinetic differences still exist. These findings

**Table 3. Summary of gait kinematics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Anterior</th>
<th>Posterior</th>
<th>Lateral</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contralateral pelvic tilt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>2.00 [–5.08 to 10.7]</td>
<td>3.07 [–1.43 to 11.85]</td>
<td>2.60 [–1.10 to 7.78]</td>
<td>0.82</td>
</tr>
<tr>
<td>6 wk</td>
<td>1.46 [–0.78 to 5.21]†</td>
<td>3.19 [0.66 to 6.46]</td>
<td>5.03 [1.92 to 10.29]†</td>
<td>0.030</td>
</tr>
<tr>
<td>12 wk</td>
<td>2.46 [–0.74 to 5.90]†</td>
<td>2.94 [–0.19 to 9.82]</td>
<td>3.96 [–1.48 to 9.39]</td>
<td>0.73</td>
</tr>
<tr>
<td>Ipsilateral trunk lean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>1.18 [–0.64 to 5.21]†</td>
<td>2.82 [–0.80 to 3.53]†</td>
<td>1.37 [0.12 to 4.72]</td>
<td>0.032</td>
</tr>
<tr>
<td>6 wk</td>
<td>0.75 [–0.48 to 2.03]†</td>
<td>1.41 [–0.97 to 4.37]†</td>
<td>3.34 [1.50 to 6.04]†</td>
<td>0.011</td>
</tr>
<tr>
<td>12 wk</td>
<td>0.88 [–1.32 to 3.06]†</td>
<td>1.72 [0.96 to 3.42]</td>
<td>2.42 [1.87 to 3.33]</td>
<td>0.042</td>
</tr>
<tr>
<td>Peak abduction angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>6.00 [3.74 to 17.81]</td>
<td>3.07 [0.48 to 7.56]</td>
<td>5.14 [0.28 to 12.91]</td>
<td>0.46</td>
</tr>
<tr>
<td>6 wk</td>
<td>5.70 [2.4 to 9.65]†</td>
<td>8.55 [4.15 to 12.99]</td>
<td>10.17 [6.98 to 13.10]†</td>
<td>0.033</td>
</tr>
<tr>
<td>12 wk</td>
<td>8.38 [3.26 to 14.07]</td>
<td>7.84 [3.32 to 11.14]</td>
<td>10.38 [5.59 to 16.65]</td>
<td>0.34</td>
</tr>
<tr>
<td>Peak flexion angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>10.16 [1.95 to 34.20]</td>
<td>6.19 [2.91 to 22.67]</td>
<td>3.52 [1.90 to 24.77]</td>
<td>0.46</td>
</tr>
<tr>
<td>6 wk</td>
<td>5.96 [0.77 to 21.96]</td>
<td>4.50 [1.18 to 12.32]</td>
<td>4.42 [–4.31 to 18.65]</td>
<td>0.94</td>
</tr>
<tr>
<td>12 wk</td>
<td>3.45 [0.66 to 15.59]</td>
<td>0.98 [–3.96 to 12.20]</td>
<td>1.12 [–7.84 to 16.13]</td>
<td>0.79</td>
</tr>
<tr>
<td>Peak extension angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>10.87 [3.12 to 34.59]</td>
<td>7.11 [1.95 to 23.50]</td>
<td>4.50 [2.82 to 25.20]</td>
<td>0.48</td>
</tr>
<tr>
<td>6 wk</td>
<td>7.21 [0.72 to 23.08]</td>
<td>5.83 [0.54 to 13.04]</td>
<td>5.46 [–4.90 to 19.45]</td>
<td>0.93</td>
</tr>
<tr>
<td>12 wk</td>
<td>4.89 [0.89 to 17.31]</td>
<td>2.50 [0.29 to 11.26]</td>
<td>2.48 [–1.23 to 12.90]</td>
<td>0.79</td>
</tr>
<tr>
<td>Peak internal rotation angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>4.94 [0.04 to 19.62]</td>
<td>7.47 [0.43 to 15.58]</td>
<td>7.10 [–2.41 to 17.10]</td>
<td>0.83</td>
</tr>
<tr>
<td>6 wk</td>
<td>1.39 [–9.74 to 17.45]</td>
<td>5.24 [–1.44 to 22.42]</td>
<td>10.37 [–5.74 to 19.03]</td>
<td>0.15</td>
</tr>
<tr>
<td>12 wk</td>
<td>1.32 [–14.08 to 6.91]†</td>
<td>4.81 [–4.41 to 18.48]</td>
<td>9.10 [–4.00 to 18.95]†</td>
<td>0.012</td>
</tr>
<tr>
<td>Peak external rotation angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>8.11 [0.80 to 15.59]</td>
<td>3.66 [0.26 to 17.88]</td>
<td>1.17 [–17.26 to 11.78]</td>
<td>0.35</td>
</tr>
<tr>
<td>6 wk</td>
<td>10.04 [0.19 to 16.61]</td>
<td>5.50 [2.79 to 18.10]</td>
<td>3.85 [0.19 to 19.89]</td>
<td>0.30</td>
</tr>
<tr>
<td>12 wk</td>
<td>10.65 [5.35 to 16.22]†</td>
<td>5.08 [–4.86 to 10.99]</td>
<td>0.98 [–2.57 to 9.11]†</td>
<td>0.010</td>
</tr>
</tbody>
</table>

*According to one-way analysis of variance; post hoc testing was completed when p < 0.05.
†Post hoc significance between the anterior and lateral group.
‡Post hoc significance between the anterior and posterior group.
§Post hoc significance between the posterior and lateral group.
Table 4. Summary of gait kinetics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Anterior</th>
<th>Posterior</th>
<th>Lateral</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak abduction moment</td>
<td>4.68 [3.16 to 5.45]</td>
<td>4.17 [2.31 to 5.51]</td>
<td>4.49 [3.12 to 5.80]</td>
<td>0.55</td>
</tr>
<tr>
<td>6 wk</td>
<td>5.04 [4.13 to 6.06]</td>
<td>5.30 [4.40 to 6.23]</td>
<td>4.28 [3.56 to 5.47]</td>
<td>0.10</td>
</tr>
<tr>
<td>12 wk</td>
<td>5.47 [4.91 to 6.36]</td>
<td>5.41 [4.33 to 7.07]</td>
<td>5.36 [4.39 to 6.21]</td>
<td>0.94</td>
</tr>
<tr>
<td>Peak flexion moment</td>
<td>2.67 [0.53 to 5.63]</td>
<td>2.60 [0.66 to 4.16]</td>
<td>2.25 [0.91 to 3.45]</td>
<td>0.63</td>
</tr>
<tr>
<td>6 wk</td>
<td>2.73 [1.56 to 3.74]</td>
<td>2.57 [1.03 to 3.51]</td>
<td>2.20 [1.10 to 3.53]</td>
<td>0.45</td>
</tr>
<tr>
<td>12 wk</td>
<td>3.11 [1.36 to 5.77]</td>
<td>3.17 [1.91 to 4.12]</td>
<td>2.80 [1.77 to 4.08]</td>
<td>0.74</td>
</tr>
<tr>
<td>Peak extension moment</td>
<td>–0.46 [–2.21 to 0.75]</td>
<td>–1.36 [–2.88 to 0.05]</td>
<td>–0.99 [–2.48 to –0.11]</td>
<td>0.13</td>
</tr>
<tr>
<td>6 wk</td>
<td>–1.00 [–1.89 to –0.59]</td>
<td>–1.62 [–2.51 to –0.71]</td>
<td>–1.08 [–2.38 to 0.05]</td>
<td>0.20</td>
</tr>
<tr>
<td>12 wk</td>
<td>–1.25 [–2.70 to –0.61]</td>
<td>–1.39 [–2.55 to –0.79]</td>
<td>–2.09 [–3.97 to –1.28]</td>
<td>0.034</td>
</tr>
<tr>
<td>Peak internal rotation moment</td>
<td>–0.38 [–0.82 to 0.004]</td>
<td>–0.40 [–0.38 to –0.15]</td>
<td>–0.64 [–1.25 to –0.19]</td>
<td>0.13</td>
</tr>
<tr>
<td>6 wk</td>
<td>–0.63 [–1.40 to –0.18]</td>
<td>–0.61 [–0.96 to –0.23]</td>
<td>–0.73 [–1.14 to –0.39]</td>
<td>0.67</td>
</tr>
<tr>
<td>12 wk</td>
<td>–0.72 [–1.36 to –0.18]</td>
<td>–0.65 [–0.97 to –0.42]</td>
<td>–0.87 [–1.38 to –0.63]</td>
<td>0.32</td>
</tr>
<tr>
<td>Peak external rotation moment</td>
<td>0.26 [0.01 to 0.49]</td>
<td>0.37 [0.05 to 0.58]</td>
<td>0.11 [–0.11 to 0.16]×†</td>
<td>0.003</td>
</tr>
<tr>
<td>12 wk</td>
<td>0.38 [0.19 to 1.14]×†</td>
<td>0.40 [0.02 to 0.76]×†</td>
<td>0.22 [–0.10 to 1.56]×†</td>
<td>0.011</td>
</tr>
<tr>
<td>Peak vertical ground reaction force</td>
<td>1.02 [0.97 to 1.10]</td>
<td>1.03 [0.97 to 1.13]</td>
<td>1.02 [0.98 to 1.05]</td>
<td>0.55</td>
</tr>
<tr>
<td>6 wk</td>
<td>1.05 [0.96 to 1.15]</td>
<td>1.04 [0.97 to 1.14]</td>
<td>1.02 [0.96 to 1.05]</td>
<td>0.47</td>
</tr>
<tr>
<td>12 wk</td>
<td>1.05 [0.99 to 1.16]</td>
<td>1.07 [1.01 to 1.20]</td>
<td>1.05 [0.97 to 1.13]</td>
<td>0.81</td>
</tr>
<tr>
<td>Peak propulsion at toe-off</td>
<td>0.10 [0.03 to 0.17]</td>
<td>0.12 [0.08 to 0.19]</td>
<td>0.11 [0.07 to 0.14]</td>
<td>0.39</td>
</tr>
<tr>
<td>6 wk</td>
<td>0.13 [0.04 to 0.22]</td>
<td>0.15 [0.12 to 0.21]</td>
<td>0.11 [0.06 to 0.16]</td>
<td>0.41</td>
</tr>
<tr>
<td>12 wk</td>
<td>0.14 [0.04 to 0.26]</td>
<td>0.17 [0.14 to 0.22]</td>
<td>0.15 [0.11 to 0.20]</td>
<td>0.54</td>
</tr>
</tbody>
</table>

*According to one-way analysis of variance; post hoc testing was completed when p < 0.05.
×Post hoc significance between the posterior and lateral group.
†Post hoc significance between the anterior and lateral group.

are statistically significant; however, the clinical relevance of these findings is limited to extrapolation based on established literature. The impact of gait anomalies on the long-term mechanical durability of implant fixation remains unknown. Future studies, such as corroborating biomechanical changes with soft tissue changes seen on cross-sectional imaging with long-term follow-up, would provide insight into how healed or unhealed tissue may explain gait aberrancies.

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Competing interests: J. Howard declares paid consultancies with DePuy, Stryker and Smith and Nephew and has received speaker fees or grants from DePuy, Stryker, Smith and Nephew, Zimmer and MicroPort. B. Lanting has received speaker fees or grants from DePuy, Stryker, Smith and Nephew, Zimmer and MicroPort. E. Vasarhelyi declares paid consultancies with DePuy and Smith and Nephew and has received speaker fees or grants from DePuy, Stryker, Smith and Nephew, Zimmer and MicroPort.

Contributors: All authors designed the study. S. Petis, I. Jones and T. Birmingham acquired and analyzed the data, which E. Vasarhelyi also analyzed. S. Petis and E. Vasarhelyi wrote the article, which all authors reviewed and approved for publication.

References


A systematic review of the factors affecting choice of surgery as a career

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See the related commentary by Acai and colleagues on p. 6

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Background: Interest in surgical careers among medical students has declined over the past decade. Multiple explanations have been offered for why top students are deterred or rejected from surgical programs, though no consensus has emerged.

Methods: We conducted a review of the literature to better characterize what factors affect the pursuit of a surgical career. We searched PubMed and EMBASE and performed additional reference checks. Agency for Healthcare Research and Quality (AHRQ) and Newcastle–Ottawa Education scores were used to evaluate the included data.

Results: Our search identified 122 full-text, primary articles. Analysis of this evidence identified 3 core concepts that impact surgical career decision-making: gender, features of surgical education, and student “fit” in the culture of surgery.

Conclusion: Real and perceived gender discrimination has deterred female medical students from entering surgical careers. In addition, limited exposure to surgery during medical school and differences between student and surgeon personality traits and values may deter students from entering surgical careers. We suggest that deliberate and visible effort to include women and early-career medical students in surgical settings may enhance their interest in careers in surgery.

Contexte : On constate que l’intérêt pour une carrière en chirurgie a décliné chez les étudiants en médecine depuis une dizaine d’années. Plusieurs raisons ont été invoquées pour expliquer le désintérêt des étudiants talentueux à l’égard des programmes de chirurgie ou leur rejet de ces programmes, sans qu’on en arrive à un consensus.


Résultats : Notre recherche a permis de recenser 122 articles de fond en texte intégral. Leur analyse a mis au jour 3 facteurs clés qui influent sur les prises de décisions concernant une carrière en chirurgie : le sexe, les caractéristiques de la formation chirurgicale et la concordance entre le profil de l’étudiant et la culture du milieu chirurgical.

Conclusion : La discrimination sexuelle réelle et perçue a détourné des étudiantes de la chirurgie comme perspective de carrière. De plus, l’exposition limitée à la chirurgie durant les études de médecine et les différences entre les traits de personnalité et les valeurs des étudiants et des chirurgiens peuvent dissuader les étudiants d’entreprendre une carrière en chirurgie. Selon nous, des efforts délibérés et tangibles d’intégration des femmes et des futurs médecins au domaine chirurgical contribueraient à accroître leur intérêt pour cette spécialité.

Declining interest in surgical careers has been of concern for more than a decade.1–4 The Canadian Resident Matching Service (CaRMS) surgical specialties have had a reduction in applications ranking surgical programs as first choice from 24.7% in 1998 to 21.7% in 2006 to 17.2% in 2016, whereas an increasing proportion of applications are to “controlled lifestyle” specialties, such as radiology, emergency medicine and anesthesiology.1–7 This is true even in historically competitive surgical specialties, such as plastic surgery.8 With increasing match participation and stable interest in surgical careers, the
quota of surgical residencies continues to be filled, but this should not be equated with increasing interest in the profession. Proportionally fewer Canadian students are applying to surgical residencies, but the rapid decline in the number of available surgical positions over the past 5 years has ensured that programs are filled.\textsuperscript{7} In the United States there has been no change in the number of available surgical positions or in the number of applications to surgical residencies over the past 5 years despite increasing numbers of total participants in the National Resident Matching Program (NRMP) Match; application to surgical residency in the United States has reduced proportionally to the overall increase in match participation.\textsuperscript{6} A 2005 survey of graduating U.S. medical students found that 45\% of first-year medical students were interested in a surgical career, whereas only 7\% of graduating students were matched to surgical residencies; findings suggested that features yet unknown during the course of medical school made surgery unpopular.\textsuperscript{3}

Effort has been made to respond to the apparent decreased interest in surgical careers among medical students by preferentially selecting high-achieving, resilient and hard-working individuals during the residency selection process. Despite this effort, residency selection is imperfect, and the quality of future surgeons is not reliably predicted by residency applications.\textsuperscript{10,11} One alternative solution to the decreased number of applications to surgical residency programs from strong candidates is to encourage early interest in surgery among medical students. We hypothesize that potentially strong candidates for surgical residency lose interest in a surgical career during medical school and subsequently do not apply for surgical residency positions. A thorough understanding of the features that attract or deter medical students from surgery must be obtained in order to expand the applicant pool for surgical training programs.

We conducted a systematic review of the published literature to clarify which factors deter students from pursuing a surgical career. The goal of this review was to facilitate active recruitment of medical students who may ultimately be interested in a surgical career, especially those who would not otherwise have considered surgery seriously.

**Methods**

This study was conducted according to the PRISMA 2009 Checklist recommendations for systematic review.\textsuperscript{12} We performed a literature search in December 2016 using PubMed with the search terms “perception of surgical career,” “surgical residency selection,” or “surgery elective undergraduate education.” We conducted a search of EMBASE using the the medical subject headings (MeSH) [focus] “Decision making,” “Surgery,” and [explode] “Medical education.” Manual reference checks of publications were performed to supplement the electronic search. We selected this strategy in an effort to identify components of the medical education processes as well as the decision-making processes in which we expect career decisions to be made. A broad search strategy was chosen owing to the variation in terminology surrounding this topic.

For the purpose of this study, medical trainees were defined as individuals in medical school or internship years who were not graduated doctors and who required supervision during clinical encounters. We considered surgical career selection to describe the decision of medical students to apply for residency training in a surgical specialty. Published randomized controlled trials and observational studies investigating trainee exposure to and interest in surgery were eligible for inclusion. No language or publication date restrictions were imposed. We included studies from all surgical specialties, including general surgery, general surgical subspecialties, vascular surgery, plastic and reconstructive surgery, neurosurgery, orthopedic surgery, otolaryngology, obstetrics and gynecology, and ophthalmology. Studies describing medical student rationale for specialty selection outside of surgery were also included. Studies that did not address our research question were excluded. Studies identified by the search strategy were initially screened by title and abstract. Full text review of and data collection from all studies meeting our inclusion criteria was performed independently by a single reviewer (J.K.P.) using a standard data extraction form.

We evaluated strength of evidence qualitatively according to the Agency for Healthcare Research and Quality (AHRQ) checklist and using the Newcastle–Ottawa Scale adapted for cross-sectional studies.\textsuperscript{13,14} The AHRQ assessment criteria grade quality of evidence based on study design, directness, precision and consistency; quality is graded as low, moderate, or high according to satisfaction of criteria in each of these categories. Directness describes whether the measured outcomes of included studies correspond to the outcome of interest for the review. Precision is defined as the degree of certainty for the included studies, and is impacted by sample size. Consistency describes whether the included studies find similar or dissimilar results. To meet criteria for high-quality evidence, a body of evidence must be largely prospective, randomized controlled trials with low risk of bias and that satisfy criteria for directness, precision and consistency. Although this tool tends to be used to assess clinical interventions, its application is useful for the evaluation of the impact certain interventions have in health care programs; we consider clinical placements and clinical training interventions among these. The Newcastle–Ottawa Scale awards studies a maximum of 10 points through the evaluation of selection, comparability and outcome criteria. Selection describes the procedures outlined in a paper to study an appropriate population. Comparability refers to how well differences between groups are accounted for. Outcome criteria refer to the risk of bias conferred by the described
Impact of gender

Gender discrimination

We chose to discuss “gender” to include the experiences of students identifying and expressing a gender different than their biological sex. Our search identified studies that used either term but that intended to communicate gender identity, and we have included them all using “gender” as the preferred term for this paper. Our search identified 13 cross-sectional studies discussing gender discrimination.15–27 An AHRQ grade of moderate strength was awarded to this body of evidence, with a mean Newcastle–Ottawa score of 6.9. The experience of gender discrimination is reported across all medical specialties, and is not unique to surgery.22 However, the perception of gender bias is frequently reported during surgical experiences and has been shown to decrease interest in the pursuit of further surgical training.15–27 This perceived culture in surgery has been described as “a gender-specific deterrence to a career in surgery for women.”26 Six large-scale surveys of medical trainees independently reported that a significant portion of female medical students experienced gender discrimination (68%–96%) and that this experience of bias influenced their career decisions.15,17–20,28 Significantly fewer female than male medical students considered surgical careers and ranked surgical residencies.20,28 In contrast, male medical students in these studies reported significantly less harassment than female medical students, and this correlated to greater interest in surgical careers.16,20,28 Gender bias was also reported as a barrier for career advancement in 4 surveys of surgeons and surgical residents, and 1 survey of 100 staff cardiothoracic surgeons reported a significant income difference between men and women and that surgeons of either gender were significantly less likely to encourage women to enter surgical careers.21,23,24,27

Lack of same-gender role models

The lack of female role models is also a frequently reported explanation for reduced interest in surgery among female students. Eleven cross-sectional studies studying the impact of same-gender role models were identified in our search.39,22,29–37 An AHRQ grade of moderate strength was awarded to this body of evidence, with a mean Newcastle–Ottawa score of 7.5. It has been shown that residency programs appearing to lack diversity are unappealing to women and other self-reported underrepresented minorities.22 Furthermore, it has been shown that female students are significantly more likely to enter specialties with a higher proportion of women.29,37 In 1 survey, as few as 35% of female medical students could identify a mentor during surgical clerkship, and a different study showed that among women who did have a mentor, 90% had a male rather than a female mentor.35,36 These findings suggest that female students may be deterred from surgical residency because there has historically been fewer women in surgery and there may be a dearth of female colleagues.

Impact of child care, pregnancy, and lifestyle considerations for women

In the studies we identified, women cited lifestyle among their most important considerations during career decision-making.18,38 The opportunity for women to lead a balanced lifestyle was reported by 10 studies to be an influential factor when deciding whether or not to pursue a surgical career.17,28,34,38,44 An AHRQ grade of moderate strength was awarded to this body of evidence, with a mean Newcastle–Ottawa score of 6.8. Among these, 4 studies reported that female students perceived general surgery to be incompatible with having children or a rewarding family life, despite 2 studies showing female staff surgeon satisfaction with their capacity to balance work and family life.17,40,42–44 Three studies identified in our search commented explicitly on maternity leave and support for child care, finding that limited or no infrastructure exists for residents who have children during training.28,19,41 One of these studies was Canadian and the other 2 were American.

Impact of surgical education

Preclerkship exposure

Exposure to surgery before students enter their clinical years has been shown to influence interest in surgery by 10 of the studies identified by our search strategy, 3 of which were cross-sectional and 7 of which were cohort studies.45–54 An AHRQ grade of moderate strength was awarded to this body of evidence, with a mean Newcastle–
Ottawa score of 6.6. The results from these studies were uniformly positive; following exposure to surgery during the preclinical years, students expressed greater confidence that surgery allows for work–life balance and meaningful change in patients’ lives.

Clinical exposure
Our literature search identified 21 studies that assessed the association between clinical exposure and student interest in surgery. An AHRQ grade of moderate strength was awarded to this body of evidence, with a mean Newcastle–Ottawa score of 7.6. Of these studies, 11 showed that clinical exposure improves student knowledge of and interest in surgery.55–65

Clerkship changed student perception of surgery and the surgical lifestyle in 6 of the studies we identified.66–71 This has a variable impact on student interest in a surgical career. Four studies reported that surgical clerkship increases student interest in surgical topics and shows the potential for work–life balance, thus increasing student interest in these careers.66,69–71 However, 2 studies reported that clerkship reduced interest in surgery. One survey of

Fig. 1. Study selection process.
African medical students showed that an anesthesiology rotation reduced interest in the career, with students citing that it clarified how this career did not achieve student goals. The other study by Zuccatto and colleagues showed that clinical exposure reduced student interest in neurosurgery from 25% to 10%, as students came to appreciate the workload of neurosurgeons. The impact of surgical simulation training on developing medical student interest in surgery was assessed in 4 studies identified by our search strategy. Surgical simulation training improved student experience of surgical clerkship in all of these studies and improved interest in surgery in 2 studies. Galiñanes and colleagues found that orientation to basic laparoscopy can benefit a student’s clerkship experience, but does not improve student interest in surgery.

Global health exposure
Global health electives in surgery are an opportunity for medical students to develop clinical experience and surgical skills in unique, often resource-limited environments. Our literature search identified 4 papers assessing medical student interest in surgery following international surgery electives. An AHRQ grade of low strength was awarded to this body of evidence, with a mean Newcastle–Ottawa score of 4.8. In these reports, a small group of medical students participated in supervised medical electives and were interviewed about their experiences. It was shown that these unique international experiences did not impair students’ ability to meet the same curricular objectives as their peers at a home site. These experiences were shown to provide a culturally broader experience and greater clinical responsibility than what was afforded to students at their home institution, though no direct comment on the impact this had on student interest in a surgical career was reported.

Impact of student fit in surgical culture

Surgical lifestyle
The surgical lifestyle and its impact on student pursuit of surgical careers was the most heavily studied association, having been discussed in 31 of the studies identified in our search. An AHRQ grade of moderate strength was awarded to this body of evidence, with a mean Newcastle–Ottawa score of 7.9. Among these, 22 studies commented explicitly on the weight that students place on duration of training and work–life balance when making career decisions. Lifestyle considerations included prolonged work hours, the perceived barrier to achieving work–life balance and the nature of patient interactions in surgery. These survey data showed that most medical students did not see their lives as compatible with surgery, and therefore considered the career-focused surgical lifestyle their primary deterrent from surgical specialties.

In contrast, medical students interested in surgery tended to consider lifestyle less important when making career decisions. Nine studies supported the theory that students who identify as surgeons prioritized their interest in surgical topics over value of a controlled lifestyle.

Efforts to enhance student interest in surgery by putting in place lifestyle modifications have had mixed success. Work hour restrictions have been shown to improve students’ experience of their surgical rotations and to enhance their interest in surgical careers. One study showed that work hour restrictions had an impact on clerkship experience and interest in surgical careers. In 2 studies of medical students completing surgical clerkships, it has been shown that these duty hour limitations produce significantly more favourable impressions of surgical lifestyles, though no statistically significant improvement in student interest in surgery was observed with the implementation of restricted work hours. In contrast, exposing medical students to community and private practice surgery has resulted in improved clerkship experience as well as enhanced interest in surgical careers, as shown by 2 studies included in our review.

Mentorship
The presence of a role model in surgery was reported in 26 studies to be a significant, positive influence on surgical career decision-making. An AHRQ grade of moderate strength was awarded to this body of evidence, with a mean Newcastle–Ottawa score of 7.8. These studies clearly showed that medical students had significantly greater interest in surgery when they were partnered with a surgical mentor. The absence of such a mentor has been shown to have a deterrent effect on student interest in surgery.

Three studies in our review discussed the role of residents as surgical mentors. These studies reported a positive association between exposure to surgical residents and interest in a surgical career. The authors of these studies suggested that residents are particularly effective mentors for medical students because of the extent to which students and residents interact.

Our search strategy revealed only 1 study that assessed the impact of mentorship outside of clinical experience. Day and colleagues reported that a mentorship program for 18 students in preclinical years of medical school was successful at improving student interest in surgical careers.

Personality type
Our search strategy identified 6 studies that sought to identify particular personality traits that predispose an individual to interest in surgery. All of these studies reported that individuals interested in surgery were significantly more extroverted and conscientious than the general population and significantly less impulsive. Inconsistency among studies existed when reporting neuroticism in the surgical personality. Emotional intelligence was not
found to be useful in differentiating medical students interested in surgical versus medical specialties.127

Our review identified 5 studies that commented on how prestige and financial reward factored into career decisions among medical students.106,128–131 These studies reported that medical students who valued prestige, financial gain and academic ambition tended to pursue careers in surgery more frequently than their counterparts, suggesting a personality that is more drawn to surgery. Furthermore, 1 study reported that medical students considered surgery to be the medical career with the greatest potential for prestige, skill and knowledge.128

An AHRQ grade of low strength was awarded to these studies, with a mean Newcastle–Ottawa score of 7.8.

**DISCUSSION**

Gender discrimination among medical students and surgeons has been discussed in the surgical literature for more than 20 years as an explanation for gender imbalances in surgical specialties. During this time, changing gender roles in society and the changing role of surgeons in the health care team has resulted in an increased inclusion of women in surgery. However, many of the studies included in this review are dated and do not reflect these changes. Furthermore, despite this progress, a position statement from the Association of Women Surgeons (AWS) expresses ongoing concern regarding gender bias causing income inequality.112

Our interpretation of the literature is consistent with the findings of the AWS that gender discrimination has deterred female interest in surgery. We propose that historical and ongoing gender discrimination has resulted in under-representation of women in surgery, especially in leadership roles and academia. This under-representation may be perceived as a “glass ceiling” hindering career development of women in surgery, thereby discouraging more women from considering careers in surgery. As effort has been made to improve representation of women in surgery, we expect this to change, but based on our findings we recommend that ongoing effort be made to demonstrate inclusion and equal opportunity within surgery.

An important means of demonstrating inclusivity and facilitating recruitment of female medical students is the explicit communication of support to those students interested in having a family; it is important to medical students that the surgical community be perceived as welcoming of diversity, encouraging of women surgeons and supportive of parental leave. Our recommendations therefore echo those of Mayer41: formal policies regarding diversity and child care support during residency should exist to ensure that students considering a family are not deterred from pursuing a career in surgery.

The perceived inability of surgeons to maintain work–life balance was another frequently reported deterrent to pursuing surgical careers and has been cited as a cause for concern among surgical training programs. Certain non-modifiable features of surgical careers, such as night call and early morning rounds, can deter students from surgery, but the data in this review suggest that clerkship may improve interest in surgical careers by dispelling the myth that surgery precludes work–life balance.68,71,118 Notably, clerkship rotations at a community hospital resulted in medical students feeling reassured that surgeons can maintain work–life balance.60,71 We recommend making an effort to ensure that work–life balance is an additional learning objective in surgical clerkship.

The data in our review emphasize the importance of early interest in surgery among medical students, as those students who have built an intellectual interest in surgery are not discouraged by the busy surgical lifestyle or the challenges surgeons face in finding work–life balance.45–54,80,82,83,85,86 The importance of exposure to surgery early in training is further supported by a study by Sallee and colleagues,128 which showed that medical student impressions of a specialty form before adequate clinical exposure in that specialty is obtained. These findings, together with ours, suggest that decisions about specialties of interest are formed during the preclerkship years. We recommend that medical students be given introductory exposure to surgery before their clerkship years in order to build early interest in surgical careers.

In addition to recruitment of medical students who are not discouraged by the busy surgical lifestyle, recruitment could be further enhanced by wellness initiatives. Surgeon wellness during residency and throughout a surgical career has become a priority, and this may encourage interest in surgery among students who are undecided.133,134 One approach to ensuring wellness among surgical trainees is the restriction of duty hours, which was found in our review to have a beneficial impact on student experience of surgery and mixed impact on student pursuit of a career in surgery.85,88,104 However, duty hour restriction is controversial, and results from prominent studies, such as the FIRST trial, illuminate the nuanced balance between duty hour policies and surgical trainee well-being.135 We cannot make recommendations based on our review regarding duty hour restrictions.

Alternative wellness initiatives and the increasing emphasis on preventing burnout among surgeons reflects a culture shift that may allow for a more balanced perception of surgical careers.115 The Royal College of Physicians and Surgeons of Canada has begun implementation of the Competence By Design (CBD) framework, which emphasizes gradual increases in responsibility as trainees advance in their knowledge and ability. Among the goals of this new curriculum is to provide a more balanced approach to exam preparation and to ensure that trainees are not held to expectations beyond their ability.136 We hypothesize that discussion of wellness during clinical training and the introduction of greater balance in training curricula will expose this emphasis on wellness to those clerks who are
yet undecided about a career in surgery and may enhance student interest in surgery.

Our review identified mentorship as having a positive impact on student interest in surgical careers. Some data suggested that resident mentors had a particularly beneficial impact on student clerkship experiences, as residents work more closely with students than staff surgeons do.\textsuperscript{106,107,115} Furthermore, mentorship of female and under-represented minority medical students has been shown to lead to similar increases in student interest in surgical careers.\textsuperscript{19,22,29–37,117}

Program diversity is an important consideration for medical students, and we posit that mentorship may allow for honest discussion of diversity in surgery and can also create a more welcoming environment for medical students who see themselves as “outsiders” in surgical settings.\textsuperscript{22,117}

Mentorship in surgery may also be beneficial because it allows students to become familiar with the personalities of potential future colleagues. The concept of a surgical personality was first developed by McGreevy and Wiebe,\textsuperscript{126} who identified similarities in trait variance on personality testing among surgical residents. Students who are extroverted, ambitious and motivated by the prestige of surgical training and the availability of surgical training positions.

Furthermore, mentorship of female and under-represented minority medical students has been shown to lead to similar increases in student interest in surgical careers.\textsuperscript{19,22,29–37,117}

Program diversity is an important consideration for medical students, and we posit that mentorship may allow for honest discussion of diversity in surgery and can also create a more welcoming environment for medical students who see themselves as “outsiders” in surgical settings.\textsuperscript{22,117}

Mentorship in surgery may also be beneficial because it allows students to become familiar with the personalities of potential future colleagues. The concept of a surgical personality was first developed by McGreevy and Wiebe,\textsuperscript{126} who identified similarities in trait variance on personality testing among surgical residents. Students who are extroverted, ambitious and motivated by the prestige of surgical work may be good candidates for surgical training.\textsuperscript{121–126,96,128–131} However, bias may exist in studies of a surgical personality among medical students: students interested in surgery may construct a value system for themselves based on that of the surgeons they know, whereby promoting personality traits unique to certain surgeons that may or may not reflect the value system inherent to surgery.

A common feature of the studies discussing the importance of mentorship is that a mentor relationship was established during clinical rotations.\textsuperscript{3,31,32,49,56,61,74,91,96,97,106–120}

Clinical experience is known to have a significant impact on career decisions, but the mentorship during exciting clinical opportunities may lead to an especially transformative experience during surgical clerkship. We encourage that mentor relationships be established with medical students whenever possible and that same-gender mentors are more favourable if available.

**Limitations**

Our outcome of interest — student interest in surgical careers — has not been shown to reliably predict pursuit of a surgical career. Only 1 study captured by our search strategy assessed match rates to surgical residency in students who reported interest in surgery, and this was not the primary outcome of the study.\textsuperscript{60} Student interest in surgery was selected a priori as our outcome of interest because it was thought to best reflect the attitudes of medical students in the process of making career decisions. Other outcomes, such as match rates to surgical residency, would not as readily report the impact that certain factors have on career decision-making and are affected by external factors, such as changes to program funding and the availability of surgical training positions.

Most studies identified in our search were cross-sectional observational studies, and many were dated. Applying these older papers to contemporary surgery is problematic, because the climate of surgery is dynamic and the evolution of culture in surgery may not yet be reflected in the literature. Because these limited-quality data were the best available, as identified by our search strategy, it is clear that there is an absence of recent, high-quality studies assessing surgical interest among medical students. We consider our results in the context of largely dated, survey-based evidence.

Strength of evidence for a heterogeneous body of largely dated, cross-sectional data, such as that assessed in our review, is difficult. Few epidemiologic tools exist to grade the strength of evidence from cross-sectional studies in a review, so we are limited in our ability to objectively grade the quality of evidence included in our review. We have applied 2 literature-validated tools for grading strength of evidence in health care programs, but these are not typically used in the context of career decision-making.\textsuperscript{13,14} Our use of multiple tools validated for different contexts attempts to overcome the limitations of using a single tool on this challenging body of evidence.

The studies that identified an association between clinical exposure to surgery and an interest in a surgical career were limited inasmuch as clerkship experiences are variable, and bias existed in the survey design.\textsuperscript{51–65} Specifically, students with early interest in surgery were more likely to seek out surgical experiences and were more inclined to report a positive clerkship experience, thereby artificially strengthening the association between exposure and interest.\textsuperscript{138}

**Conclusion**

The goal of this review was to clarify which deterrents to entering surgical careers were perceived by medical students. Real and perceived gender discrimination detered female medical students from entering surgical careers. In addition, limited exposure to surgery and the operating room during medical school and real and perceived differences between student and surgeon personality traits and values may deter students from entering surgical careers. Some evidence identifies a unique surgical personality that could be identified in medical students, but the application of this to recruitment efforts has not yet been validated in the literature. Evidence supports the matching of students with surgical mentors to encourage surgical careers. Those students ambivalent toward careers in surgery may have enhanced interest in surgical careers if they are mentored, included in clinical work from early stages of training, and made to feel part of the surgical team; we suggest that faculty and residents consider these factors when working with medical students.

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Affiliations: From the Faculty of Medicine, University of British Columbia, Vancouver, BC (Peel); and Canadian Surgical Technologies and Advanced Robotics (CSTAR), London Health Sciences Centre and Department of Surgery, Schulich School of Medicine and Dentistry, Western University, London, Ont. (Schlachta, Alkhamesi).

Competing interests: None declared.

Contributors: All authors designed the study. J. Peel acquired and analyzed the data. J. Peel and N. Alkhamesi wrote the article, which all authors reviewed and approved for publication.

References

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Can surgical site infections be reduced with the adoption of a bundle of simultaneous initiatives? The use of NSQIP incidence data to follow multiple quality improvement interventions

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Surgical site infections (SSI) are a common complication after surgical procedures and have substantial associated health care costs.1 The SSI bundle — simultaneous implementation of a variety of quality improvements — has proven successful at reducing the rate of postoperative SSIs in a number of institutions.1-3 Oakville Trafalgar Memorial Hospital, a 469-bed facility in Oakville, Ont., instituted an SSI bundle in October 2015 based on best available evidence and the understanding of infection pathophysiology. We used National Surgical Quality Improvement Program data on the incidence of SSIs in our targeted and essentials, general surgery and orthopedic surgery cases before and after the implementation of an SSI reduction bundle. This article discusses whether the use of intervention bundles may assist in the reduction of a variety of postoperative surgical complications.

Our bundle

The following quality-improvement measures were implemented simultaneously in order to reduce the rate of SSIs at our institution.
- Preoperative shower (chlorhexidine gluconate 4%)
- Preoperative mechanical bowel preparation (sodium picosulfate, magnesium oxide, and citric acid) and oral antibiotics (2 g of neomycin and 2 g of metronidazole) taken at 7 pm and 9 pm, respectively, the evening before colon resection
• Hair clipping, if needed, to be done outside the operating room (OR)
• No routine performance of open appendectomy (laparoscopic appendectomy preferred)
• Preoperative antibiotics (e.g., 2 g of cefazolin, 3 g if the patient weighs more than 120 kg, and redose if the surgery is longer than 4 h)
• Proper preoperative skin preparation and technique
• Double gloving and changing outer gloves every 60 minutes
• Use of fascial wound protector
• Closing bundle and glove change, with extensive pressurized wound irrigation for laparotomies
• Education on minimizing OR traffic

The interventions

Preoperative showering with soap or specialized antiseptic solutions, such as chlorhexidine gluconate, has been shown to reduce the risk of SSIs. We developed a preoperative instruction sheet (Appendix 1, available at canjsurg.ca/006417-a1).

Mechanical bowel preparations combined with oral antibiotics have been shown to reduce SSIs in patients who undergo colonic resection. We instituted preoperative bowel preparation with sodium picosulfate, magnesium oxide, and citric acid combined with 2 g of neomycin and 2 g of metronidazole administered at 7 pm and 9 pm, respectively, the evening before the procedure.

To reduce particulate dispersion in the OR, we moved hair clipping, in cases where it is required, from the OR to a dedicated clipping zone.

Laparoscopic appendectomy is associated with a significantly decreased risk of SSI compared with open appendectomy. At our institution only 1 surgeon out of 7 routinely performed open appendectomies before institution of the SSI bundle, and when presented with this information, he switched to the laparoscopic approach.

The latest recommendations for preoperative prophylactic antibiotics for SSI reduction suggest the routine use of 2 g of cefazolin, (3 g in patients who weigh more than 120 kg), with redosing for surgical procedures lasting longer than 4 h.

Skin preparation protocols varied at our institution, and we switched to single-use sponges presoaked with a measured quantity of 2% chlorhexidine gluconate and 70% isopropyl alcohol with a standardized method (Appendix 1).

Surgical glove perforation exposes patients to the skin flora of operating personnel and exposes operating personnel to the patient’s bloodborne pathogens. Double gloving has been instituted as routine policy at our institution.

The fascial wound protector has been postulated as a mechanism to reduce subcutaneous fatty tissue and fascial exposure to skin flora and intraluminal gastrointestinal flora (Fig. 1). For laparotomies we have recommended the routine use of an inexpensive bowel bag (e.g., Vi-Drape Isolation Bag, Cardinal Health), which can be easily turned into a fascial wound protector by cutting off the bottom. We have recently started using the Alexis O retractor (Applied Medical).

The gloves and the instruments used in a case can be exposed to skin flora or gastrointestinal organisms. At the end of a laparotomy we have instituted the use of closing trays (Fig. 2), and for laparotomies we use the Pulsevac Plus (Zimmer Biomet) battery-powered, pressurized irrigation system to irrigate the subcutaneous fatty tissue.

Modern OR laminar airflow systems are designed to reduce particulate density at the level of the OR table. We have instituted an educational campaign and appropriate signage (Fig. 3) so that personnel enter ORs through the central sterile core when cases are underway.
Results
In the 6-month preintervention period of April to September 2015, our overall SSI rate was 3.4% (28 of 828 cases). With the introduction of our SSI bundle, the overall SSI rate dropped to 1.0% (9 of 844 cases, \( p = 0.001 \); Table 1)

Traditional methods of patient care can be very difficult to change. We adapted the Johns Hopkins Comprehensive Unit-Based Safety Program model to create our surgical quality initiative team (SQUINT), with a core group that meets every 2 weeks and a larger group that includes representatives from the emergency department, surgical wards, OR, anesthesiology, general surgery, orthopedic surgery, urology and surgical administration that meets monthly. Regular communication and an openness to bidirectional learning have allowed the rapid implementation of multiple changes.

Conclusion
It can be difficult to have a study adequately powered to show improvements in outcomes for some interventions. Consequently, the bundle approach with the simultaneous implementation of multiple measures based on best practices, available studies and the understanding of disease pathophysiology has been recommended to improve complication rates, despite the lack of overwhelming and convincing evidence of individual efficacy. It is quite possible that a synergistic effect occurs when these multiple low-impact interventions are combined.

The NSQIP-ON collaborative allows the sharing of information and quality-improvement measures to allow all participants access to each other’s insights, regardless of success.

Acknowledgements: The author thanks Carmen Caloian, the surgical clinical reviewer upon whose tireless efforts rest the successes of their NSQIP program, and Neeta Bahia, Professional Practice Clinician in the operating room for her persisting efforts in education. In addition, the author thanks Julie McBrien, Program Director of Surgery at Halton Healthcare Services, for guiding their implementation of NSQIP and the program delivery team at Health Quality Ontario for their support in introducing NSQIP and many quality improvement measures to Ontario.

Competing interests: None declared.

References
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ABDOMINAL ORGAN TRANSPLANT SURGEON
Division of General Surgery, Department of Surgery
University Health Network
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The Division of General Surgery, in the Department of Surgery at the University Health Network and the University of Toronto are inviting applications for a full-time faculty position as an academic Abdominal Organ Transplant Surgeon at the level of Associate Professor. The effective date of this position is August 1, 2018.

The successful candidate will support the clinical programs and academic mission of University Health Network, an academic institution affiliated with the University of Toronto. University Health Network is comprised of the Toronto General Hospital, Toronto Western Hospital, Princess Margaret Cancer Centre, Toronto Rehabilitation Institute, and the Michener Institute. The transplant program at UHN is recognized internationally for excellence in patient care, innovation, research and education. The Division of General Surgery currently has 25 surgeons, 7 of whom specialize in Abdominal Organ Transplantation.

Responsibilities will include liver, kidney, and pancreas transplant surgery, on-call, practical and didactic teaching of general surgery residents, as well as abdominal organ transplant fellows. This position entails 20 to 30 hours of didactic undergraduate medical student teaching per year, in addition to supervision of 10 to 20 on-service medical students per year.

The successful candidate will have clinical experience in living donor liver transplantation as well as pediatric liver transplantation. In addition, the successful candidate must have previous experience with robot assisted laparoscopic donor nephrectomies. She/he will have experience in fellow and resident education, preferably with experience as a transplant fellowship program director. She/he will have experience in research and an interest in quality improvement programs and implementation of quality improvement standards and protocols. Evidence of productivity, excellence, and the potential to become an international leader is essential. Start-up research support and mentoring will be provided.

The successful candidate will have completed a residency program in general surgery as well as an American Society of Transplant Surgeon (ASTS) accredited fellowship in abdominal organ transplantation, (or equivalent) with an emphasis on liver, kidney, and pancreas transplantation. She/He will have demonstrated outstanding technical skills, the ability to work within a multidisciplinary team and to teach trainees at all levels. She/He will hold, or be eligible for, licensure with the College of Physicians and Surgeons of Ontario. She/He will hold a FRCSC from the Royal College of Physicians and Surgeons of Canada, or equivalent.

Starting salary will be between the range of $400,000-$500,000 commensurate with qualifications and experience. This estimate is based on fee for service billings, in addition to support from the University Health Network Division of General Surgery practice plan.

Please submit a letter of intent, CV and the name of three referees by March 31, 2018 to:

Allan Okrainec, MD, MHPE, FRCSC, FACS
Head, Division of General Surgery, UHN
Peter A. Crossgrove Chair in General Surgery
Toronto General Hospital
10 Eaton Room 220, 200 Elizabeth St.
Toronto, Ontario, Canada M5G 2C4

Questions and correspondence should be directed to: Deborah Wilson, email deborah.wilson@uhn.ca, tel 416 340-3573.

The University of Toronto is strongly committed to diversity within its community and especially welcomes applications from visible minority group members, women, Aboriginal persons, and persons with disabilities, members of sexual minority groups, and others who may contribute to the further diversification of ideas. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

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ASSOCIATE PROFESSOR OR FULL PROFESSOR
HEPATO-PANCREATO-BILIARY SURGERY

Division of General Surgery, Department of Surgery
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The Division of General Surgery, in the Department of Surgery at the University Health Network and the University of Toronto are inviting applications for a full-time faculty position as the Section Head of the Hepato-pancreato-biliary (HPB) Surgery Program in the Division of General Surgery, at the level of Associate or Full Professor. The effective date of this position is flexible, but preferably July 2018.

The successful candidate will lead the Hepato-pancreato-biliary program and the academic mission of the Division of General Surgery at University Health Network, which is an academic institution affiliated with the University of Toronto. The University Health Network is comprised of the Toronto General Hospital, Toronto Western Hospital, Princess Margaret Cancer Centre, Toronto Rehabilitation Institute, and the Michener Institute. The HPB surgery program at UHN is recognized internationally for excellence in patient care, innovation, research and education. The Division of General Surgery currently has 25 surgeons, 6 of whom specialize in HPB surgery. Case volumes place the HPB Program within the busiest programs in North America.

Responsibilities will include surgery, on-call, practical and didactic teaching of general surgery residents, as well as HPB/Transplant clinical fellows, all of whom are on service continuously. As the HPB section head, he/she will report to the Division Head of General Surgery. Administrative responsibilities will include oversight of the HPB surgery program including clinical and research academic initiatives. The successful applicant will have demonstrated a strong academic commitment, manifested by prior publications and international collaborations in the field of interest. Evidence of productivity, excellence, and international leadership is essential.

The successful candidate will be an actively practicing HPB surgeon and will have completed a residency program in general surgery as well as an HPB fellowship. She/He will have demonstrated outstanding technical skills, the ability to work within a multidisciplinary team and to teach trainees at all levels. It is expected that the successful candidate will bring their special expertise in research or education to the role. She/He will have strong leadership skills, as demonstrated by prior leadership roles. She/He will hold, or be eligible for, licensure with the College of Physicians and Surgeons of Ontario. She/He will hold a FRCS from the Royal College of Physician and Surgeons of Canada, or equivalent. A graduate degree (Masters or PhD) would be an asset.

Starting salary will be between the range of $400,000-$500,000 commensurate with qualifications and experience. This estimate is based on fee for service billings, in addition to support from the University Health Network Division of General Surgery practice plan.

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Intraoperative ultrasonic cholangiography for biliary system identification

We read with great interest the paper “Intraoperative ultrasonography of the biliary tract using saline as a contrast agent: a fast and accurate technique to identify complex biliary anatomy” by Chandra and colleagues. They reported that saline sonocholangiography (SSC) provided excellent images for correct identification of segmental bile duct anatomy during surgery of the biliary tract, and was a simple and inexpensive technique that could be performed with minimal resources.

We recently developed contrast-enhanced intraoperative ultrasonic cholangiography (CE-IUOCS) using perfluorobutane microbubbles (Sonazoid; Daiichi-Sankyo Pharmaceutical Co., Japan) as a tool for real-time biliary navigation in various hepatobiliary operations. This technique enables 3-dimensional mapping and visualization of the 2-dimensional regional anatomy of the biliary tree. In addition, we reported that CE-IUOCS could delineate the biliary drainage areas of the liver parenchyma belonging to a bile duct orifice with a clear dividing line as a pseudostaining region. We think that CE-IUOCS and SSC are similar in concept but use different contrast agents, although both contrast agents consist of saline and bubbles. We would like to point out several concerns.

We feel that concentration and persistence time of the contrast agent are key factors for success of ultrasonic cholangiography imaging and real-time biliary navigation. At higher concentrations of the contrast agent, acoustic shadowing induced by condensed microbubbles in bile ducts interferes with ultrasound imaging. At lower concentrations, the echogenicity of bile ducts is reduced, preventing their visualization against a background of hyperechoic surrounding tissues, such as those in the hilar plate. In the study by Chandra and colleagues, a high concentration of saline bubbles in the bile duct cast a sonic shadow that interfered with imaging of structures in the liver beyond the bile duct. We emphasize that CE-IUOCS can be performed using a stable contrast agent concentration because dilution is performed in the same manner as for intrabiliary injection, compared with use of saline bubbles made of churned air, which are too unstable for optimal concentration. The short contrast agent persistence time requires frequent injections for real-time anatomic identification of the biliary tree. In addition, the short persistence time interferes with imaging of smaller bile duct branches, such as the caudate branches. In fact, the authors reported that echogenicity lasted for only for 1–2 minutes or less in some patients. This duration is too short for real-time biliary navigation. This is why we selected perfluorobutane microbubbles as a contrast agent for CE-IUOCS. We agree that saline bubbles are less expensive, but speculate that bubbles made from saline and air churning lack important characteristics adequate for use as a contrast agent for CE-IUOCS.

Lastly, we emphasize the importance of performing hepatobiliary operations without complications. We hope that novel intraoperative ultrasonic cholangiography techniques without radiation exposure, such as CE-IUOCS or SSC, will be widely used to reduce biliary complications during hepatobiliary operations.

Takeshi Urade, MD, PhD; Takumi Fukumoto, MD, PhD

Affiliations: From the Department of Surgery, Division of Hepato-Biliary-Pancreatic Surgery, Kobe University Graduate School of Medicine, Kobe, Japan (Urade, Fukumoto); and the Department of Surgery and Digestive Surgery, Kita-Harima Medical Center, Ono, Japan (Urade).

Competing interests: None declared.

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References


Author response

We thank Drs. Urade and Fukumoto for their comments on our paper. Urade and colleagues described contrast-enhanced intraoperative ultrasonic cholangiography for real-time biliary navigation using perfluorobutane microbubbles in their 2014 study, referenced in our paper. As they mentioned, one limitation of their study was the use of a specific contrast agent and 3D ultrasound probes, which may not be available across all centres, as in our case. We studied the feasibility of using saline, churned with room air as a contrast agent along with a 2D ultrasound probe as an alternative. As mentioned by Drs. Urade and Fukumoto, achieving a specific concentration and stability of saline bubbles was not possible in our study, and this also explains variations in the amount of echogenicity and contrast retention time seen on our ultrasound images. These variations are also mentioned in our results. Constant saline injection in the
indwelling catheter obviates the loss of echogenicity due to “unstable contrast.” Also, saline microbubbles may wash out earlier than perfluorobutane microbubbles, thus creating less interference with further imaging. We thank Drs. Urade and Fukumoto for referring to their recent papers, in which they described “pseudostaining” of the liver parenchyma caused by perfluorobutane microbubbles leading to accurate identification of the duct. In our study, use of intrabiliary saline sharply demarcated the segment(s) to which the duct belongs and was clearly visible as parenchymal echogenicity on ultrasound imaging. Primarily, this is how we have identified the duct in our technique and is very similar to “pseudostaining.” The echogenicity caused by saline may be less intense than perfluorobutane microbubbles; however, it still sharply demarcates the respective segment(s). Necessity is the mother of invention, and we propose that our technique will be of value to a hepatobiliary surgeon when making intraoperative decisions with minimal resources.

Abhijit Chandra, MD, MCh

Affiliation: From the Department of Surgical Gastroenterology, King George Medical University, Lucknow, India.

DOI: 10.1503/cjs.1861012

CORRECTION OF PLACE OF PRACTICE: BRAMPTON, NOT BRANTFORD

I read with interest the editorial in the December 2017 issue, “Dr. Louis Kristal at 100: witness to the evolution of surgery in Canada.” I practised orthopedic surgery in Brampton from 1974 to 2010. I knew Lou well as a GP/anesthesiologist and subsequently as a GP surgical assistant. I enjoyed his discussions with interested physicians in the “Doctor’s Lounge” on Saturday mornings. He was a staunch Liberal, and I was always careful to steer clear of some of the political controversies at the time.

I am pleased to see he has an excellent memory at 100!

Dr. Kristal’s practice in 1974 for 10 years was in Brampton, not Brantford, as the article states.

Donald Prior, MD

Affiliation: Former Chief of Surgery (retired), Peel Memorial Hospital and William Osler Health Centre, Brampton, Ont.

Competing interests: None declared.

DOI: 10.1503/cjs.1861013

References


AUTHOR RESPONSE

Many thanks to Dr. Prior for his letter about our recent editorial on Dr. Louis Kristal. The journal has corrected the place of practice in the online version of the article.

Regrettably, Dr. Kristal passed away, not long after the editorial was published, on Dec. 8, 2017.

Vivian McAlister, MB

Affiliation: Coeditor, Canadian Journal of Surgery.

DOI: 10.1503/cjs.1861014
The coeditors in chief, on behalf of the Canadian Journal of Surgery Editorial Board, acknowledge with thanks the cooperation of the following reviewers in 2017.

Au nom du conseil de rédaction du Journal canadien de chirurgie, les corédacteurs remercient les examinateurs suivants de leur collaboration en 2017.

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