Teaching surgery takes time: the impact of surgical education on time in the operating room

Christopher Vinden, MD
Richard Malthaner, MD, MSc
Jacob McGee, MD, MSc
J. Andrew McClure, MSc
Jennifer Winick-Ng, MSc
Kuan Liu, MMath,
Danielle M. Nash, MSc
Blayne Welk, MD, MSc
Luc Dubois, MD, MSc

Submitted on behalf of the Surgical Investigators Group at ICES Western: Sumit Dave, Eric Frechette, Sarah Jones, Sarah Knowles, Danielle MacNeil, Dave Nagpal, Stephen E. Pautler, Kelly Vogt.

Correspondence to:
C. Vinden
London Health Sciences Centre, Victoria Hospital
800 Commissioners Rd E
Rm E2-218
London ON N6A 5W9
chris.vinden@lhsc.on.ca

Background: It is generally accepted that surgical training is associated with increased surgical duration. The purpose of this study was to determine the magnitude of this increase for common surgical procedures by comparing surgery duration in teaching and nonteaching hospitals.

Methods: This retrospective population-based cohort study included all adult residents of Ontario, Canada, who underwent 1 of 14 surgical procedures between 2002 and 2012. We used several linked administrative databases to identify the study cohort in addition to patient-, surgeon- and procedure-related variables. We determined surgery duration using anesthesiology billing records. Negative binomial regression was used to model the association between teaching versus nonteaching hospital status and surgery duration.

Results: Of the 713 573 surgical cases included in this study, 20.8% were performed in a teaching hospital. For each procedure, the mean surgery duration was significantly longer for teaching hospitals, with differences ranging from 5 to 62 minutes across individual procedures in unadjusted analyses (all $p < 0.001$). In regression analysis, procedures performed in teaching hospitals were associated with an overall 22% (95% confidence interval 20%–24%) increase in surgery duration, adjusting for patient-, surgeon- and procedure-related variables as well as the clustering of patients within surgeons and hospitals.

Conclusion: Our results show that a wide range of surgical procedures require significantly more time to perform in teaching than nonteaching hospitals. Given the magnitude of this difference, the impact of surgical training on health care costs and clinical outcomes should be a priority for future studies.

Contexte : Il est généralement admis que la formation chirurgicale est associée à des interventions plus longues. L'objectif de la présente étude était de déterminer l'ampleur de cette augmentation pour les chirurgies courantes en comparant la durée des interventions dans les hôpitaux universitaires et les autres hôpitaux.

Méthodes : Dans le cadre d'une étude de cohorte rétrospective basée sur la population, nous avons recensé tous les résidents adultes de l'Ontario (Canada) qui ont subi une intervention chirurgicale parmi une liste de 14 entre 2002 et 2012. À l'aide de plusieurs bases de données administratives reliées, nous avons constitué la cohorte de l'étude et recueilli des variables associées aux patients, aux chirurgiens et aux interventions. Nous avons déterminé la durée des opérations à partir des dossiers de facturation d'anesthésiologie. Une régression binomiale négative a été utilisée pour modéliser le lien entre le statut des hôpitaux — universitaires ou non — et la durée.

Résultats : Des 713 573 chirurgies à l'étude, 20,8 % ont eu lieu dans un hôpital universitaire. Dans tous les cas, la durée moyenne était significativement plus longue dans les hôpitaux universitaires, les écarts variant de 5 à 62 minutes pour chaque intervention dans les analyses non corrigées ($p < 0,001$ dans tous les cas). Selon l'analyse de régression, les chirurgies effectuées dans les hôpitaux universitaires étaient associées à une augmentation globale de la durée de 22 % (intervalle de confiance à 95 %, 20 %–24 %), après ajustement pour les variables liées aux patients, aux chirurgiens et aux interventions ainsi que pour la densité de patients pris en charge par les chirurgiens et les hôpitaux.

Conclusion : Nos résultats montrent que de nombreuses interventions chirurgicales durent considérablement plus longtemps dans les hôpitaux universitaires que dans les autres hôpitaux. Étant donné l'ampleur de cet écart, l'étude de l'incidence de la formation chirurgicale sur les coûts des soins de santé et les résultats cliniques devrait être une priorité pour les recherches futures.

Training the next generation of surgeons is an integral part of a sustainable health care system. Surgical training is associated with decreased operative efficiency owing to the time required for instruction in addition to the slower operative speed of trainees compared with senior surgeons.[1–8] Given the long duration of surgical residency, surgical training can result in substantial cumulative inefficiency, which impacts cost as well as access to limited surgical resources. Previous research has also demonstrated a consistent association between prolonged surgery duration and adverse patient outcomes across a wide range of procedures.[9–20]

Although previous research has shown that trainee involvement is associated with prolonged surgical duration,[1–8] the magnitude of this increase has not been estimated at a population level, nor has previous research adjusted for patient- and surgeon-related factors, such as experience of the attending surgeon. Administrative data from the province of Ontario are ideal to address this research question because surgical training in Ontario is concentrated within a limited number of teaching hospitals, such that the impact of training on surgery duration can be estimated by comparing teaching and nonteaching hospitals.

The objective of this study was to establish robust, population-based estimates of the time premium associated with operative training for a variety of common surgical procedures, adjusting for patient-, surgeon- and procedure-related variables. Results from this study can be used by administrators, policy-makers and legislators to make informed decisions about sustainable funding for surgical education and will provide a benchmark for surgical educators as they balance operative efficiency and trainee participation with the potential for adverse time-dependent surgical outcomes.

METHODS

Study setting and design

Residents of the province of Ontario, Canada, (population 13.4 million in 2012)[21] have universal access to hospital care and physician services. Private delivery of such services is prohibited, meaning that all eligible procedures performed in the province are recorded in administrative databases. Relevant data sets were linked using unique, encoded identifiers and analyzed at ICES Western, a satellite site for the Institute for Clinical Evaluative Sciences (ICES) in Toronto, Ont.

In Ontario, surgical and anesthesiology training is concentrated in hospitals associated with 6 medical schools. Nonteaching services in teaching hospitals are rare, and in most programs residents outnumber staff, meaning that it is reasonable to assume that a resident will be present at almost all procedures performed in a teaching hospital. Residents rotate through community hospitals for a small proportion of their overall training. When present in a community hospital, residents would typically replace a surgical assistant.

In this retrospective, multicentre, population-based cohort study, all adult residents of Ontario who underwent any of the index procedures (see the section on procedures and data sources) between Apr. 1, 2002, and Mar. 31, 2012, were included. Cases were excluded if the patient was younger than 18 years, if the procedure was performed emergently or during out-of-office hours (evening, weekend, or holiday; not for appendectomy or hip fracture), if the surgery was for a recurrent condition, if the attending surgeons' main specialty was atypical for the procedure, or if the surgery was performed without an anesthesiologist (involvement of anesthesiology was required to calculate the outcome). Elective procedures (except tonsillectomy, which is rarely performed with an assistant) performed in nonteaching hospitals were excluded if an assistant did not submit a valid payment claim for the surgery because it was thought that such surgeries may be more likely to include resident assistants. Finally, 2 geographic areas encompassing less than 1.5% of the Ontario population were excluded owing to concerns regarding procedure coding accuracy in those areas. The number of cases excluded at each step is presented in Appendix 1, Table S1 (available at canjsurg.ca).

Procedures and data sources

A panel of experts selected procedures from various surgical specialties that represent common procedures that are often managed in both teaching and community settings, but rarely require referral to tertiary care centres. Procedures included laparoscopic cholecystectomy, right hemicolectomy, appendectomy, unilateral inguinal hernia repair, hysterectomy, hip hemiarthroplasty, open reduction and internal fixation (ORIF) for hip fracture, hip and knee arthroplasty, and tonsillectomy (see Appendix 1, Table S2 for coding information); where applicable, open and laparoscopic procedures were considered separately.

Surgeon and patient characteristics were ascertained from 5 linked health care administrative databases: the Canadian Institute for Health Information (CIHI) Discharge Abstract Database (DAD) and Same Day Surgery (SDS) databases (includes diagnostic, procedural and clinical patient data), the Ontario Health Insurance Plan (OHIP) database (contains health claims), the Registered Persons Database (vital statistics for all residents of Ontario) and the ICES Physician Database (information for all physicians practising in Ontario).

We created exposure groups based on the type of hospital (teaching v. nonteaching) in which the index procedure was performed. Hospital type was determined using a list of academic hospitals published by Health Force Ontario,[22] all of which have surgical training programs. The number of hospitals in each group fluctuated slightly over time

owing to openings, closures and mergers. In the final year (2012) we identified 19 teaching hospitals and 159 nonteaching hospitals. Although 1 medical school (Northern Ontario School of Medicine) began providing postgraduate training during the study period, the 2 hospitals associated with this program were classified as nonteaching because of the very small number of residents enrolled during the timeframe of this study. The impact of this decision should be minimized by the exclusion of procedures performed at nonteaching hospitals without an assistant. There are no known surgical training programs at any other nonteaching hospitals included in the study.

Variable definitions

Duration of surgery was determined on the basis of anesthesiology billing records, using the methodology validated by Redelmeier and colleagues.[23] In Ontario, anesthesiologists submit fee-for-service billings through OHIP, with fees calculated according to a standardized algorithm based on service units. Service units related to surgery duration represent the entire time that the anesthesiologist is in attendance with the patient and are recorded in 15-minute intervals; therefore, times calculated based on these units should include all physician teaching activities that occur during the encounter.

We determined patient complexity using the Johns Hopkins ACG (adjusted clinical group; ACG software version 10) methodology.[24] This method of case-mix grouping captures all morbidities for which a patient receives care during a defined period — in this case, 3 years before the procedure date. The ACGs can be collapsed into 6 resource utilization bands (RUBs) on the basis of expected use of health care resources. In the present study, we used the CIHI-DAD, CIHI-SDS, CIHI–National Ambulatory Care Reporting System (NACRS) and OHIP databases to calculate RUBs, which were summarized as a 3-point ordinal variable: 1 = low (RUB = 0–3), 2 = moderate (RUB = 4) and 3 = high (RUB = 5).

Statistical analysis

We conducted all analyses using SAS software version 9.3 (SAS Institute). Differences in baseline variables between teaching and nonteaching hospitals were assessed using standardized differences, with an effect size threshold of > 0.2 used to identify meaningful differences. We assessed differences in mean surgery duration using t tests. As surgery duration is a non-negative integer, it is appropriate to model it using a count data model, such as Poisson or negative binomial regression. In this case, where overdispersion was present, we used negative binomial regression to assess the association between surgery duration and teaching hospital status, controlling for patient age, sex, obesity (body mass index [BMI] > 40), complexity (RUB),

anesthetic technique, procedure year and procedure type (only for analyses involving multiple procedures). We additionally controlled for surgeon-related variables, including age, sex and annual procedure-specific volume (determined using the OHIP database). To account for the clustering effect of patients within surgeons and hospitals, we used the generalized estimating equations approach.

We conducted 3 additional sensitivity analyses to assess the presence of referral bias, whereby more difficult, potentially longer-duration cases are referred to teaching hospitals. Two of these analyses used the Ontario Multispecialty Network (OMN) database[25] to identify each patient's expected admitting hospital. The OMN assigns Ontario residents to an expected admitting hospital using a 2-step process: individuals are linked to a "usual provider of care," and providers are linked to hospitals. The OMN also aggregates select hospitals into hospital networks, such that the expected place of admission can be 1 of several individual hospitals within the network (i.e., the patient's expected admitting hospital network). In the first sensitivity analysis, the cohort was limited to procedures performed at the patient's expected admitting hospital, whereas the second was limited to procedures performed within the patient's expected admitting hospital network. In the final sensitivity analysis, the cohort was limited to patients defined as having a low level of complexity (RUB = 1). All 3 sensitivity analyses involved the same statistical approach used for the primary analyses.

RESULTS

Of the 713 573 surgical procedures included in this study, 148 538 (20.8%) were performed in a teaching hospital, representing 11.7%–39.8% across the individual procedures. Across all procedures, the mean duration of surgery was significantly longer for procedures performed in teaching than nonteaching hospitals, with mean differences ranging from 5 to 62 minutes across the individual procedures and all comparisons significant at $p < 0.001$ (Table 1). In negative binominal regression analyses adjusting for patient-, surgeon- and procedure-related variables, teaching hospitals were associated with significantly longer surgery durations than nonteaching hospitals for all of the procedures studied (Fig. 1). Across the 14 procedures, teaching hospitals were associated with an overall 22% (95% confidence interval [CI] 20%–24%) increase in surgery duration, ranging from 8% for hip arthroplasty to 33% for open right colectomy.

Patients treated in teaching and nonteaching hospitals were similar in regards to baseline characteristics (Appendix 1, Table S3a-c). While a slightly higher proportion of complex patients (as ascertained by the RUBs) were treated in teaching hospitals than nonteaching hospitals (26.0% v. 21.5%), most of the baseline differences identified were not clinically significant. Similarly, surgeons operating in

teaching and nonteaching hospitals did not meaningfully differ, with the exception that surgeons operating in teaching hospitals tended to perform a greater number of the index procedures per year (mean total of 51.8 ± 43.6 v. 43.3 ± 41.3 procedures).

An increase in surgical duration was evident over the study period in both teaching and nonteaching hospitals for all procedures except elective hip and knee arthroplasty. Overall mean duration increased from 114 minutes in 2002 to 125 minutes in 2011 across the 14 procedures. Post hoc analysis of this unexpected finding suggests that this increase is largely explained by the transition from

open to laparoscopic techniques over the study period for several of the included procedures (data not shown).

We conducted 3 sensitivity analyses to investigate the potential impact of referral bias using the same analytic methods used for the main analysis and adjusting for the same covariates. Exclusion of patients who were not admitted to their expected hospital and/or hospital network (on the basis of OMA hospital assignment) did not change our findings, with teaching hospitals remaining significantly associated with increased duration for each procedure type. Again, we obtained similar findings when the cohort was restricted to patients with a low level of complexity. Results

Table 1. Mean duration of surgery by hospital type and unadjusted difference in surgery duration comparing teaching to nonteaching hospitals (in minutes)

Procedure	Nonteaching		Teaching		Mean difference (%)*
	No.	Mean ± SD	No.	Mean ± SD	
Laparoscopic cholecystectomy	129 369	97 ± 29.9	25 554	119 ± 43.2	23 (23.3%)
Laparoscopic right hemicolectomy	4538	200 ± 53.3	2185	238 ± 65.2	39 (19.3%)
Open right hemicolectomy	6584	165 ± 52.3	2696	226 ± 92.3	62 (37.5%)
Laparoscopic appendectomy	34 404	98 ± 29.3	8887	127 ± 36.7	29 (29.5%)
Open appendectomy	24 106	89 ± 33.7	3574	109 ± 46.3	20 (21.9%)
Laparoscopic inguinal hernia repair	6705	87 ± 24.9	1562	105 ± 35.7	19 (21.3%)
Open inguinal hernia repair	65 904	82 ± 22.1	12 002	95 ± 35.1	14 (16.7%)
Laparoscopic hysterectomy	4400	177 ± 60.8	2906	217 ± 62.9	40 (22.6%)
Open hysterectomy	59 381	127 ± 36.1	16 299	154 ± 53.7	27 (21.4%)
ORIF for hip fracture	33 674	118 ± 35.6	8149	154 ± 55.0	36 (30.4%)
Hip hemiarthroplasty	19 872	138 ± 37.0	5448	173 ± 47.3	35 (25.2%)
Hip arthroplasty	53 000	152 ± 36.8	24 930	157 ± 39.2	5 (3.2%)
Knee arthroplasty	96 559	149 ± 33.1	30 820	158 ± 39.5	9 (6.3%)
Tonsillectomy	26 539	60 ± 16.0	3526	68 ± 25.7	8 (13.0%)
Overall	56 5035	115 ± 43.7	148 538	144 ± 54.7	29 (25.0%)

ORIF = open reduction and internal fixation; SD = standard deviation.
*Mean time in teaching – mean time in nonteaching hospitals. Significant at $p < 0.001$ for each procedure.
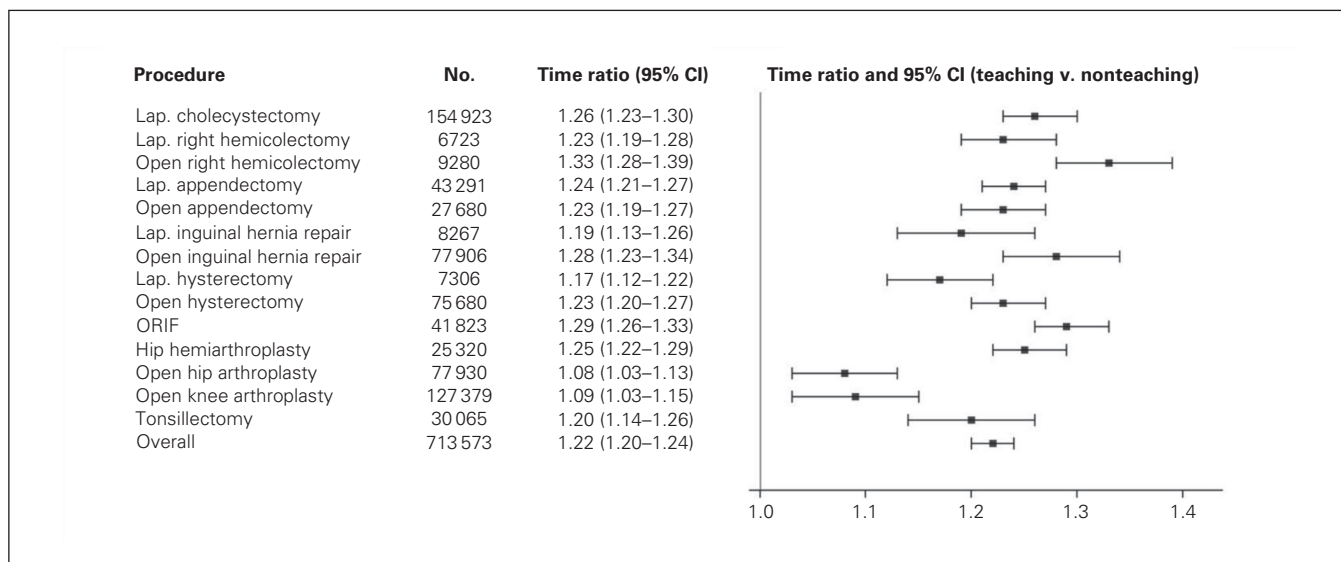

Procedure	No.	Time ratio (95% CI)
Lap. cholecystectomy	154 923	1.26 (1.23–1.30)
Lap. right hemicolectomy	6723	1.23 (1.19–1.28)
Open right hemicolectomy	9280	1.33 (1.28–1.39)
Lap. appendectomy	43 291	1.24 (1.21–1.27)
Open appendectomy	27 680	1.23 (1.19–1.27)
Lap. inguinal hernia repair	8267	1.19 (1.13–1.26)
Open inguinal hernia repair	77 906	1.28 (1.23–1.34)
Lap. hysterectomy	7306	1.17 (1.12–1.22)
Open hysterectomy	75 680	1.23 (1.20–1.27)
ORIF	41 823	1.29 (1.26–1.33)
Hip hemiarthroplasty	25 320	1.25 (1.22–1.29)
Open hip arthroplasty	77 930	1.08 (1.03–1.13)
Open knee arthroplasty	127 379	1.09 (1.03–1.15)
Tonsillectomy	30 065	1.20 (1.14–1.26)
Overall	713 573	1.22 (1.20–1.24)

Fig. 1. Operative time ratio comparing surgery duration in teaching and nonteaching hospitals, adjusted for patient-, surgeon- and procedure-related variables (see the Statistical analysis section for a complete description of covariate adjustment). CI = confidence interval; Lap = laparoscopic; ORIF = open reduction and internal fixation.

for the sensitivity analyses are presented in Appendix 1, Figs. S1–S3.

DISCUSSION

This robust analysis of more than 700 000 cases demonstrates that surgery duration is prolonged in teaching compared with nonteaching hospitals over a wide range of commonly performed procedures. On average, procedures performed in teaching hospitals take 22% longer to complete, with an even greater increase for more complex procedures. The magnitude of this difference suggests a negative impact on both patient outcomes and clinical efficiency. There are many differences between teaching and nonteaching hospitals, with teaching hospitals tending to have larger volume, higher acuity and a greater focus on research. Beyond the impact of these disparities, we propose that factors associated with surgical training likely account for the vast majority of the observed increase in surgery duration.

Prolonged surgery duration has been linked previously to surgical training,[1–8] yet few studies have controlled for patient or surgeon factors. Our study confirms these findings by accounting for a wide range of patient and surgeon factors and by generating a robust estimate of the time premium associated with surgical training. This study also differs from previous literature in that we looked at total duration of surgery, defined as the duration of involvement by anesthesiologists, rather than the time from incision to skin closure. Our definition includes all aspects of the operative intervention, including positioning, prepping, draping and insertion of monitoring catheters and lines within the operating suite. Moreover, this definition accounts for all teaching activities that occur within the operating suite, including training of surgical and anesthesiology residents. This metric is potentially more useful from the perspective of both patients and policy-makers, as it encompasses the entire case and all associated resources.

The difference in surgery duration between teaching and nonteaching hospitals was much lower for elective hip and knee arthroplasty than for other procedures, with increases of 8% and 9% in adjusted analyses, respectively. We speculate that specialization within dedicated arthroplasty teams may partly explain this finding. Within Ontario teaching centres, arthroplasty procedures are predominantly performed by surgeons who specialize in arthroplasty and work with dedicated teams, whereas community-based arthroplasty is typically performed by general orthopedic surgeons in nondedicated units. This contrasts with the other procedures we studied, which are often performed by generalists and, although common, rarely dominate a surgeon's practice in either teaching or nonteaching settings. Whether such efficiencies can be achieved by adopting specialized units for other common procedures is an obvious question posed by this research.

Although investigation of surgical outcomes was beyond the scope of the present study, previous research has demonstrated a consistent association between surgery duration and adverse surgical outcomes.[9–20] This association likely reflects multiple confounding factors, including the observation that complex and challenging cases take longer and are associated with higher complication rates. Disentangling the impact of teaching time from other factors that increase surgical duration will be a considerable challenge for future research to address. Quantifying the added operative time that is an inherent component of surgical training represents an important contribution to the debate regarding the effect of trainees on patient outcomes. Future research should aim to identify thresholds that are indicative of excess risk of complications across various surgical procedures.

Limitations

As a large, population-based study, the present study allows for precise estimates and wide generalizability. However, because this study was limited to the data available within administrative databases, it was not possible to adjust for some of the variables known to contribute to surgery duration, such as procedure complexity (e.g., size of hernia). Similarly, no information was available regarding the resident's experience level or extent of participation, nor was it possible to confirm resident involvement in individual cases. Although this study encompassed the entire training period of several annual cohorts of residents, we were also unable to assess the impact of trainee seniority. Another potential weakness is that we estimated surgery duration on the basis of billing data rather than direct measurement; however, it is unlikely that any bias introduced using this method would have a differential impact on estimates for teaching and nonteaching hospitals.

CONCLUSION

This population-based study of more than 700 000 cases suggests that trainee involvement significantly increases surgery duration. The magnitude of this increase is large enough to potentially affect direct and indirect costs, institution and surgeon efficiency, and possibly impact surgical outcomes. Our findings with respect to arthroplasty further suggest that the impact of teaching may be reduced when surgical training is delivered in the context of procedure-specific teams. These data provide a benchmark for surgical educators as they strive to meet the needs of their trainees without compromising efficiency or safety. Finally, our study provides robust population-level data allowing policy-makers to include the time costs of surgical training into funding models.

Affiliations: From the Department of Surgery, Divisions of General Surgery (Vinden), Thoracic Surgery (Malthaner), Urology (Welk) and Vascular Surgery (Dubois), and the Department of Obstetrics and Gynaecology (McGee), Western University, London, Ont.; and the Institute for Clinical Evaluative Sciences, Toronto, Ont. (Vinden, McClure, Winick-Ng, Liu, Nash, Welk).

Competing interests: None declared.

Contributors: All authors designed the study and interpreted the results. J. Winick-Ng was responsible for data extraction and analysis. C. Vinden wrote the article, which all authors reviewed and approved for publication.

References

1. Pollei TR, Barrs DM, Hinni ML, et al. Operative time and cost of resident surgical experience: effect of instituting an otolaryngology residency program. *Otolaryngol Head Neck Surg* 2013;148:912-8.
2. Tseng WH, Jin L, Canter RJ, et al. Surgical resident involvement is safe for common elective general surgery procedures. *J Am Coll Surg* 2011;213:19-26.
3. Kiran RP, Ali UA, Coffey JC, et al. Impact of resident participation in surgical operations on postoperative outcomes: National Surgical Quality Improvement Program. *Ann Surg* 2012;256:469-75.
4. von Strauss Und Tomey M, Dell-Kuster S, Mechera R, et al. The cost of surgical training: analysis of operative time for laparoscopic cholecystectomy. *Surg Endosc* 2012;26:2579-86.
5. Papandria D, Rhee D, Ortega G, et al. Assessing trainee impact on operative time for common general surgical procedures in ACS-NSQIP. *J Surg Educ* 2012;69:149-55.
6. Advani V, Ahad S, Gonczy C, et al. Does resident involvement effect surgical times and complication rates during laparoscopic appendectomy for uncomplicated appendicitis? An analysis of 16,849 cases from the ACS-NSQIP. *Am J Surg* 2012;203:347-51.
7. Babineau TJ, Becker J, Gibbons G, et al. The "cost" of operative training for surgical residents. *Arch Surg* 2004;139:366-9.
8. Bridges M, Diamond DL. The financial impact of teaching surgical residents in the operating room. *Am J Surg* 1999;177:28-32.
9. Jackson TD, Wannares JJ, Lancaster RT, et al. Does speed matter? The impact of operative time on outcome in laparoscopic surgery. *Surg Endosc* 2011;25:2288-95.
10. Campbell DA, Henderson WG, Englesbe MJ, et al. Surgical site infection prevention: the importance of operative duration and blood transfusion — results of the first American College of Surgeons National Surgical Quality Improvement Program best practices initiative. *J Am Coll Surg* 2008;207:810-20.
11. Fogarty BJ, Khan K, Ashall G, et al. Complications of long operations: a prospective study of morbidity associated with prolonged operative time (> 6 h). *Br J Plast Surg* 1999;52:33-6.
12. Scheer A, Martel G, Moloo H, et al. Laparoscopic colon surgery: Does operative time matter? *Dis Colon Rectum* 2009;52:1746-52.
13. Bech-Larsen SJ, Lalla M, Thorup JM. The influence of age, duration of symptoms and duration of operation on outcome after appendicitis in children. *Dan Med J* 2013;60:A4678.
14. Leong G, Wilson J, Charlett A. Duration of operation as a risk factor for surgical site infection: comparison of English and US data. *J Hosp Infect* 2006;63:255-62.
15. Chu D, Bakaeen FG, Wang XL, et al. Does the duration of surgery affect outcomes in patients undergoing coronary artery bypass grafting? *Am J Surg* 2008;196:652-6.
16. Chan MM, Hamza N, Ammori BJ. Duration of surgery independently influences risk of venous thromboembolism after laparoscopic bariatric surgery. *Surg Obes Relat Dis* 2013;9:88-93.
17. Gastmeier P, Sohr D, Breier A, et al. Prolonged duration of operation: an indicator of complicated surgery or of surgical (mis)management? *Infection* 2011;39:211-5.
18. Rambachan A, Mioton LM, Saha S, et al. The impact of surgical duration on plastic surgery outcomes. *Eur J Plast Surg* 2013;36:707-14.
19. Kim JYS, Khavanin N, Rambachan A, et al. Surgical duration and risk of venous thromboembolism. *JAMA Surg* 2015;150:110-7.
20. Daley BJ, Cecil W, Clarke PC, et al. How slow is too slow? Correlation of operative time to complications: an analysis from the Tennessee Surgical Quality Collaborative. *J Am Coll Surg* 2015;220:550-8.
21. Statistics Canada. Table 051-0001 — Estimates of population, by age group and sex for July 1, Canada, provinces and territories, annual (persons unless otherwise noted), CANSIM (database). Available: www5.statcan.gc.ca/cansim (accessed 2014 Nov. 27).
22. Health Force Ontario. Appendix A: Group A Hospitals. Available: www.healthforceontario.ca/en/M4/Clerkship_Travel_Program/Program_Guidelines/Ontario_Academic_Health_Science_Centres (accessed 2014 Aug. 6).
23. Redelmeier DA, Thiruchelvam D, Daneman N. Introducing a methodology for estimating duration of surgery in health services research. *J Clin Epidemiol* 2008;61:882-9.
24. The John Hopkins University Bloomberg School of Public Health. Health Services Research & Development Center. The John Hopkins ACG® Case-Mix System Version 6.0 Release Notes. (Editor in Chief: Jonathan P. Weiner). The John Hopkins University, 2003.
25. Stukel TA, Glazier RH, Schultz SE, et al. Multispecialty physician networks in Ontario. *Open Med* 2013;7:e40-55.