Systematic review and meta-analysis of operative experiences of general surgery trainees during training

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Background: General surgical training curricula around the world set defined operative numbers to be achieved before completion of training. However, there are few studies reporting total operative experience in training. This systematic review aimed to quantify the published global operative experience at completion of training in general surgery.

Methods: Electronic databases were searched systematically for articles in any language relating to operative experience in trainees completing postgraduate general surgical training. Two reviewers independently assessed citations for inclusion using agreed criteria. Studies were assessed for quantitative data in addition to study design and purpose. A meta-analysis was performed using a random-effects model of studies with appropriate data.

Results: The search resulted in 1979 titles for review. Of these, 24 studies were eligible for inclusion in the review and data from five studies were used in the meta-analysis. Studies with published data of operative experience at completion of surgical training originated from the USA (19), UK (2), the Netherlands (1), Spain (1) and Thailand (1). Mean total operative experience in training varied from 783 procedures in Thailand to 1915 in the UK. Meta-analysis produced a mean pooled estimate of 1366 (95 per cent c.i. 1026 to 1707 procedures per trainee at completion of training. There was marked heterogeneity between studies (I^2 = 99.6 per cent).

Conclusion: There is a lack of robust data describing the operative experiences of general surgical trainees outside of the USA. The number of surgical procedures performed by general surgeons in training varies considerably across the world.

Introduction

It is important that surgeons are trained adequately and are able to deliver high-quality care to patients. There has been a global trend towards the standardization of surgical training with the setting of curricula, with the aim of improving the quality and safety of surgical services by ensuring surgeons are trained to specified criteria. This began in the 1990s with the Canadian Medical Education Directives for Specialists (CanMEDS) framework of competencies for training[1]. Since then, several other countries have adopted competency-based models for surgical training with defined curricula[2-5]. Although there is a framework for competency achievement in Canada, there is no minimum operative experience standard stated. However, several surgical curricula around the world set minimum numbers of operations to be achieved during general surgical training[6-10], presumably in light of the reported association between high surgeon operative volume and improved patient outcomes[11-13].

However, there is no worldwide standardization of expected operative experience in general surgical training, and surgical curricula requirements differ. For example, the UK demands 1600 procedures by completion of training[7] and the USA requires 750[6], although both programmes have the intention of training surgeons to a standard for independent practice. There appears to be little evidence for the setting of minimum numbers, with the threshold setting for numbers of procedures in the UK based on limited evidence from just 58 trainees who had completed training over a 2-year period[14]. Some curricula, such as those in the UK, define types of procedure required, with minimum numbers to be met for index procedures such as hernia repair, cholecystectomy and emergency laparotomy[7]. The length of surgical training also varies around the world, and trainee working weeks differ, ranging from 48 h in Europe[15] to 80 h in the USA[16]. These combined aspects are likely to influence the opportunities for gaining experience in general surgical training, with the potential for wide variation in the operative experience of newly qualified surgeons around the world.

To date there has been no comprehensive review of the operative experience at completion of general surgical training worldwide and its variation between countries. This study aimed to identify and summarize the available literature relating to operative experience at completion of general surgical training worldwide.

Methods

Search strategy

The study team developed a concept table and built a search strategy with a medical librarian to identify articles reporting operative experience in general surgical training. Three concepts were developed: graduate education, operative surgical procedures and general surgery. Exploded medical subject heading (MeSH) terms were combined with text word searching using the Boolean operator ‘OR’ for each concept. Each concept was combined with ‘AND’.

Synonyms for surgical trainees, such as resident, chief resident and registrar, were used in addition to alternative names for training programmes (for example surgical training, residency training and specialty training). Terminologies for specifically named surgical curricula were included with both full terms and acronyms (such as Intercollegiate Surgical Curriculum Programme, ISCP) along with logbook names for the regions that use a single, compulsory logbook (for example eLogbook). A term was deleted from the search strategy if it yielded no results (such as morbidity audit and logbook tool).

No search limits were applied and all languages were included. Five databases were searched (Ovid MEDLINE R, 1996 to present, Ovid MEDLINE In-Process, Educational Resources Information Centre (ERIC), Psycinfo, British Education Index) and the search strategy was adapted to each database. The final search was performed in November 2015.

Reference lists of included articles were also searched and further articles included if appropriate. The search strategy used is summarized in *Table S1* (supporting information).

National bodies for surgical training were also contacted by e-mail with a request for any unpublished data (Royal Australasian College of Surgeons, Royal College of Physicians and Surgeons of Canada, The College of Surgeons of Hong Kong, French Association of Surgery).

Exclusion criteria

Studies were excluded if the article did not report a number of operations performed in training, was based on simulation or was not related to surgery. Any studies reporting data from medical students or junior trainees (foundation or core training in the UK, intern year in the USA) were excluded. Studies were included only if they reported operative experience data for trainees at completion of an entire higher surgical training programme.

Selection of articles

Two of the study authors independently assessed the study titles and abstracts for inclusion. They discussed and resolved any differences in title selection between them. A third assessor independently reconciled any differences in abstract selection. Authors were contacted directly to provide articles that were not available online or through library services. Google Translate and multilingual colleagues were used to aid assessment of non-English language articles.

Data extraction

One author extracted information from the studies using a standardized spreadsheet. Data extracted included study year, study design and purpose, numerical data for total operations and procedure-specific operations. Procedures included were inguinal hernia repair, appendicectomy, cholecystectomy and segmental colectomy, with both open and laparoscopic approaches recorded where given. These procedures were chosen as they comprise key ‘index’ procedures that form essential competency requirements in several general surgical training systems[7, 17, 18]. Total procedure-specific data were calculated by summing open and laparoscopic totals in articles that presented open and laparoscopic data separately. Where only laparoscopic data were presented for cholecystectomy, this was taken as a proxy for total operating, given the high frequency of the laparoscopic approach for cholecystectomy in recent surgical practice[18-22]. Total number of operations per graduating trainee was calculated from the published data if a paper presented total numbers of operations performed by graduating trainees and the total number of graduating trainees.

Study selection for meta-analysis

The outcome for the meta-analysis was total number of operations completed in training. Studies were included if they reported data from a national single logbook, mean total number of operations per trainee at completion of training, sample size and a measure of variance. Both the UK and USA surgical curricula specify minimum total numbers of operative procedures to be completed throughout training, which must be exclusive of endoscopic procedures[3, 23]. Therefore, endoscopy numbers were excluded from the data in the meta-analysis. The data from 1999 published by Eckert and colleagues were not included in the meta-analysis to keep included studies contemporaneous.

Study authors were contacted to provide further data where necessary. Allum and colleagues[14] and Thomas *et al*.[24] provided raw data for further analysis. Aphinives[18] provided further statistical parameters on request. The authors of one study did not respond to a request for additional statistics. A rate of total number of operations per trainee per year of training was calculated by using total operation data and length of respective training programme for studies included in the meta-analysis.

Statistical analysis

Raw data from Allum *et al.*[14] and Thomas and co-workers[24] were used to calculate mean total number of operations (excluding endoscopy) and standard deviation. Standard errors were calculated from the standard deviation and sample size reported by each included study. A random-effects meta-analysis of the included studies was undertaken. A random-effects model was chosen as there were obvious differences in total operations between the included studies. Heterogeneity of the studies was assessed using I^2 test. All data management and analysis were performed using Stata® version 14 (StataCorp, College Station, Texas, USA).

Results

Search results

Some 1979 titles (560 abstracts, 66 full papers) were identified which, following screening, resulted in 24 full articles for inclusion in the study. Five studies were included in the meta-analysis from four countries (*Fig. 1*). None of the national bodies for surgery that were contacted provided further data relating to operative experience.

Demographics of included studies

Of the 24 included studies, 19[19-22, 25-39] were from the USA, one[40] from the Netherlands, one[18] from Thailand, one[41] from Spain and two[14, 24] from the UK (*Table 1*). Sixteen studies[19, 21, 22, 25-34, 36, 37, 39] from the USA used Accreditation Council for Graduate Medical Education (ACGME) logbook data to assess a national cohort of graduating trainees in a series of cross-sectional analyses. The other US studies used ACGME logbook data from local training cohorts[20, 35] or hospital registry data[38]. Non-US studies used national[14, 18, 24, 41] or regional[40] cohorts, hospital registry[40] and electronic logbook[14, 18, 24, 41] data. Half of the studies had a focus on the impact of working hour regulations on operative experiences in training[33-36, 40], or the impact of minimally invasive surgery on operative experience[22, 26, 29-32, 38]. The 24 studies span nearly two decades of surgical training, with the earliest studies reporting data from 199[37, 39] and the most recent data reported from 2013[24]. Overlapping data reporting was seen among the 16 studies[19, 21, 22, 25-34, 36, 37, 39] that used ACGME logbook data, with several studies reporting the same data periods. The number of trainees included in the studies varied from 15[20] to more than 9000[31]. Eight[26, 28-30, 32, 34, 36, 38] studies did not report the size of the cohort investigated. Seventeen studies[14, 18, 20-22, 24, 25, 27, 28, 31, 33-36, 38, 40, 41] reported total operative experience, with ten[18,19,24–26,29–32,37] reporting appendicectomy data, 12[14, 18, 20, 21, 24-27, 30-32, 37] hernia data, 12[14, 18-22, 24-26, 30, 37, 38] cholecystectomy data and 13 studies[14, 18-21, 24-27, 30, 32, 37, 39] documenting colectomy data. Of the 12 studies reporting data relating to cholecystectomy, five[18-22] reported data only for laparoscopic procedures rather than open or combined data. Inclusion and exclusion criteria varied, with only three studies[14, 18, 40] stating exclusion of trainees who worked less than full time, had not completed training or completed training periods for research out of programme. Quality of data reporting varied widely among studies, with both mean and medians reported; several studies did not report ranges, measures of variance or sample sizes.

Total operating experience

Of the 17 studies reporting total operative experience, three[14, 21, 25] included endoscopy numbers. Data for total operative experience is shown in *Table 2*.

Six of the US studies reported mean total procedures completed in training for national cohorts of graduating trainees, with endoscopy excluded. These studies reported a range of means of between 879 and 967 procedures.[22, 27, 31, 33, 34, 36] Sachs et al reported median total procedures completed in training for a national cohort of graduating trainees, excluding endoscopy, with a range of medians between 903 and 976 procedures.[28] Two studies from the USA included endoscopy in total procedures and reported a range of total procedures between a median 1023 procedures and mean 1264 procedures.[21, 25] In the UK, Thomas and colleagues[24] reported a median total number of procedures per trainee at completion of training of 1802. Analysis of the additional raw data from Allum and co-workers[14] found a median of 1876 procedures (mean 1915) and a range of 1102–2931 operations per UK completing trainee. From a study of trainees in the Netherlands, Hopmans *et al.*[40] reported a range of 1291–1490 for mean number of procedures per graduating trainee. Data from Spain reported by Serra-Aracil and colleagues[41] describe similar numbers, with a mean of 1325 operations per completing trainee. In Thailand, Aphinives[18] reported a mean of 783 procedures per completing trainee.

Procedure-specific operating experience

Seventeen studies[14, 18-22, 24-27, 29-32, 37-39] reported data for appendicectomy, cholecystectomy, colectomy or hernia repair. All but three[14, 18, 24] of the studies were from the USA (*Table 3*)

Appendicectomy

Ten studies[18, 19, 24-26, 29-32, 37] reported appendicectomy-specific data. Total appendicectomy experience in training in the USA ranged from a mean of 31 procedures[37] to a mean of 63 operations[19]. Seven[19, 25, 26, 30-32, 37] of the studies from the USA reported ACGME data for a national cohort of graduating trainees with the same data reported in multiple studies. The only study[24] from the UK to describe appendicectomy experience in training reported that trainees performed a median of 121 appendicectomies during the course of their training, with a range of 21 to 316 procedures. Data from Thailand reported that trainees performed a mean of 73 procedures per graduating trainee[18].

Inguinal hernia

Twelve studies[14,18,20,21,24–27,30–32,37] reported procedure-specific data for inguinal hernia surgery. Studies from the USA reported a range from 53[37] to 71[26] mean hernia repairs per trainee. An outlying US study[20] reported a mean of 113 hernia repairs per trainee. UK studies[14, 24] reported that trainees performed a mean of 90 and median of 92 inguinal hernia repairs per completing trainee. Aphinives[18] reported substantially fewer hernia repairs per trainee with a mean of 18 procedures.

Cholecystectomy

Twelve studies[14, 18-22, 24-26, 30, 37, 38] reported procedure-specific data for cholecystectomy experience. Studies published from the USA from the year 2000 onwards[19-21, 25, 26, 30], reporting both open and/or laparoscopic cholecystectomy data, reported mean total experience ranging from 88[21] to 118[25,30] procedures. The USA trainee experience in cholecystectomy was similar to the UK experience, with Allum *et al.*[14] reporting a mean of 96 procedures and

Thomas and colleagues[24] a median of 103 operations. Aphinives[18] reported a mean of 6 laparoscopic cholecystectomies per trainee at completion of training.

Colectomy

Thirteen studies[14, 18-21, 24-27, 30, 32, 37] reported procedure-specific data for colectomy. In the UK, Thomas and co-workers[24] noted a median of 42 colectomies per trainee, whereas Allum *et al.*[14] documented a mean of 33 procedures per trainee.[14, 24] Studies from the USA reported a varied colectomy experience of between a mean of 34[37,39] and 69[27] procedures per graduating trainee. Aphinives[18] reported a mean of 5 segmental colectomies per completing trainee in Thailand.

Meta-analysis

A meta-analysis of data from five studies[14, 18, 24, 27, 40] produced a mean pooled estimate of 1366 (95 per cent c.i. 1026 to 1707) procedures per trainee at completion of training. The I^2 value of 99.6 per cent confirms the significant heterogeneity between the studies (*Fig. 2*).

For the studies included in the meta-analysis, mean total operating per trainee per year of training varied from 183 procedures in the USA[27] to 319 operations in the UK[14]. Trainees in Thailand performed a mean of 196 procedures per trainee per year[18] and those in the Netherlands a mean 232 of procedures per trainee per year[40]. Trainees in the UK performed a mean of 307 and 319 procedures per trainee per year[14, 24] (*Table 4*).

Discussion

This systematic review has three key findings. First, there is limited literature available relating to the operative experiences of surgeons in training, particularly outside of the USA. Second, there is wide variation in the total number of procedures undertaken by a trainee general surgeon, both within training systems and between countries. For example, Bell and colleagues[21] reported a range of 600–2785 procedures per trainee in the USA and Thomas *et al.*[24] documented a range of 783–3764 procedures per trainee in the UK; both studies highlighted the differing operative experiences of trainees, despite training within the same time frame and curriculum. Global variation in total operations per qualifying trainee is apparent, with a difference between a mean of 783 procedures in Thailand[18] and 1915 in the UK[24], suggesting widely differing procedural experience of newly qualified surgeons around the world. Third, this study has demonstrated variation in the number of key ‘index’ procedures performed by surgical trainees worldwide.

This review was performed according to the methodology for systematic review set out in the PRISMA checklist[42]. Careful planning of search criteria in association with an experienced medical librarian, inclusion of all languages, independent duplicate reviewing of the titles and abstracts, and standardized data extraction contribute to the credibility and strength of this study. Obtaining original data and parameters relating to the papers included in the meta-analysis allowed these papers to be included.

This systematic review is limited by potential biases within the included studies. The accuracy of the logbook data is reliant upon trainees inputting their operative experiences precisely. However, as several of the studies originate from training systems that set minimum number requirements for completion of training, trainees are likely to be motivated to keep exact records of their operative experiences. Publication bias also affects this study; suitable data for meta-analysis were available from just five studies[14, 18, 24, 27, 40], representing four countries. This limits the generalizability of the meta-analysis results when considering global operative experience. The purpose of performing the meta-analysis was to explicitly quantify the study heterogeneity and variation in total operative experience. That there is statistically significant heterogeneity is shown in the I^2 value of 99.6 per cent.

This literature reported numerical operative experience in general surgery training from only five countries (USA, UK, the Netherlands, Spain and Thailand), which highlights the lack of evidence underpinning the curricula that require minimum operative experience thresholds. Several of the included studies were limited by the absence of reporting of sample size, standard deviation or interquartile range. The adoption of a single electronic logbook by a training system would enable the reporting of the operative experience of trainees, as demonstrated by the higher volume of research published using national ACGME data[19, 21, 22, 25-34, 36, 37, 39].

This review and meta-analysis has described variation in the total numbers of procedures achieved during general surgical training around the world. Differences in data reporting partly account for the variation, with some studies[14, 18, 20, 22, 24, 27, 28, 31, 33-36, 38, 40] documenting only total major procedures and others[21, 25] reporting all procedures including endoscopy.

Differing curricula and varying requirements for minimum operative experience at completion of training are likely explanations for the variation in total operative experience. The ISCP sets the curriculum for UK general surgical trainees[3]. It states that trainees should undertake a minimum of 1600 procedures and defined numbers of index procedures (appendicectomy 80, inguinal hernia repair 60, cholecystectomy 50, segmental colectomy 20, emergency laparotomy 100, Hartmann's procedure 5). The total operating numbers may include procedures in which the trainee played an assisting role, whereas index procedures must be performed by the trainee, either under supervision or unsupervised.[7]

The American Board of Surgery (ABS) provides board certification to individuals who have met the Residency Review Committee for Surgery (RRC-S) standards of training. In contrast to the UK, the ABS sets out terms of requirements for completion of training in the *Booklet of Information: Surgery*, and stipulates minimum operative experience of 750 major procedures to be completed by the end of residency training (including at least 150 major operations in the chief resident year)[6]. The ABS states that trainees must have 'personally performed either the entire operative procedure or the critical parts thereof' in order that the trainee may count the operation as a major procedure[6]. This description of trainee involvement is akin to the non-assisting codes that UK trainees abide by for counting operations towards index procedure requirements[43]. The difference in the qualification of procedures towards total operating experience will explain some of the difference between the UK and USA total procedure numbers, but does not affect procedure-specific data. Allum and colleagues[14] reported that 66 per cent of total operative experience was recorded as the trainee performing the operation, either supervised or unsupervised. Two-thirds of the mean total experience reported by Allum *et al.* represents some 1264 procedures and remains in excess of reported USA trainee total operative experience. As in the UK, total major procedures in the USA must be exclusive of endoscopy, critical care procedures and very minor procedures such as banding of haemorrhoids[23].

Trainees in Thailand are expected to perform 500 operations during training, to and meet procedure-specific requirements for inguinal hernia (10), cholecystectomy (7) and colectomy (3)[18]. General surgery trainees in Spain[17] and the Netherlands do not presently have to attain minimum total procedural requirements (J. Hamming, Programme Director for Surgical Training, The Netherlands; personal communication). However, the Spanish curriculum sets procedure-specific requirements including inguinal hernia (25) cholecystectomy (15) and colectomy (10)[17].

Where there are data available for comparison with national curricula, trainees generally exceed minimum training requirements. Thomas and colleagues[24] and Allum *et al.*[14] both described UK mean total operative experience in excess of the minimum requirement. All of the studies from the USA[19-22, 25-39] reported total operative experience in excess of the minimum requirement, as did Aphinives[18] in Thailand. However, given the wide ranges of experience, it is likely that a small proportion of trainees do not meet the national minimum standards for operating experience at completion of training. The difference in standard setting between countries is also striking, with the UK specifying minimum numbers far higher than those in the other systems.

The smaller number of index procedures completed by trainees in the USA, compared with the UK, probably reflects that total operative experience is less than that in the UK despite the differences described in the criteria for minimum total number of operations. In the case of cholecystectomy, some of the variation between studies might be explained by the reporting of laparoscopic cholecystectomy alone. This may under-represent total cholecystectomy numbers in training for these studies[18-22]. There is an outlying study[20] from the USA describing hernia surgery experience vastly in excess of that in other US studies. This was a local study of only 15 trainees and is perhaps not reflective of national hernia surgery experience. Aphinives[18] reported that trainees perform a relatively large number of appendicectomies in training in Thailand. This may reflect differences in types of surgical procedures performed in Thailand or perhaps a different expectation of the role of trainees.

Other surgical training systems do not set minimum operative experience targets for completion of training. For example, in Australia and New Zealand, trainees are expected to achieve 100 major procedures per 6-month placement, but no minimum numbers are absolutely required of trainees and no data describing the trainee operative experience have been assessed.

Canada has adopted a competency-based system of education. The Royal College of Physicians and Surgeons of Canada have clear recommendations for the future of surgical training and assessment in Canada, with no minimum operative experience requirements[44]. Szasz and colleagues[45] recently conducted a Delphi consensus process among Canadian general surgery programme directors, and developed a list of procedures that could be considered as essential for competency as a general surgeon. No reference was given to the volume of operative experience expected in these procedures, rather that competency should be assessed using work-based assessments.

Variation in training programme duration is a further likely explanation for the variation between operative experiences of trainees between countries. Working hours also differ between the systems, with US residents working to an 80-h working week[16] and European trainees limited to a 48-h working week[15]. However, even when accounting for differences in length of training, European trainees still appear to complete more operations per year of training than their USA counterparts despite working fewer hours per week (*Table 4*). Additionally, although each of the training systems described aspires to train surgeons to a standard for competent, independent practice, concerns have been expressed that US trainees are inadequately prepared for independent surgical practice at the end of residency training[21]. Furthermore, up to 80 per cent of graduating US residents seek further training through a period of fellowship training[45, 46] and less than 1 per cent of graduating residents plan to commence immediately with a career as an attending general surgeon[47]. However, nearly 80 per cent of UK trainees also complete some form of post-Certificate of Completion of Training (CCT) training period[48].

How much operating a general surgery trainee needs to complete in training is neither well defined nor evidenced-based. The Joint Committee for Surgical Training (JCST) set minimum total and index procedure operating experience requirements for the 2013 UK curriculum[7] based on the study by Allum and colleagues[14] of 58 trainees awarded CCT in 2010–2011. This relatively arbitrary setting of operative experience targets followed concerns that trainees were being deemed competent to perform a procedure (as judged by the procedure-based assessment, the tool adopted by the UK for skill assessment) without the necessary volume of procedures to experience a range of operative complexities[14]. However, the use of trainee logbooks alone (without an associated assessment of competency) to set minimum operative experience requirements is probably more representative of the numbers the small sample of trainees were able to achieve within the confines of the training system rather than an evidence-based reflection of competency.

The ABS specified a minimum of 750 total major procedures for US general surgery trainees in 2008, an increase from the previous criteria of 500 operations[49]. These numbers were based on a consensus judgement by directors of the ABS and are also unrelated to a measure of competency (F. Lewis, Executive Director, American Board of Surgery; personal communication).

In 2009, Bell and co-workers[21] expressed concerns that trainees completing general surgery training in the USA had inadequate operative experience in specific operations that programme directors identified as procedures a completing trainee should be able to perform independently. They suggested that inadequate operative experience was unlikely to confer competency in these essential procedures. Allum *et al.*[14] acknowledged the unknown number of procedures required to achieve competency and suggested that further analysis of competency assessment data and operative experience data may help to determine this.

The relationship between procedural experience and competency attainment is not well understood in postgraduate surgical training, but has been investigated in the field of endoscopy. Ward and colleagues[50] studied the learning curve of doctors training to perform colonoscopy in the UK, with reference to standards for minimum numbers in training programmes. The authors analysed the numbers needed to reach competency as defined by a standardized measure (90 per cent caecal intubation rate), and were able to show that current minimum colonoscopy experience targets are appropriate[50]. Wani and co-workers[51] assessed learning curves in trainees undertaking endoscopic retrograde cholangiopancreatography (ERCP) training in the USA. They concluded that specific levels of procedural experience do not ensure competence in ERCP.

De Siqueria and Gough[53] have studied the association between operative experience in general surgery and the attainment of competency in the UK. They found that trainees performed more operations than current UK requirements for CCT before achieving competency, and concluded that minimum procedural experience did not accurately reflect competence. This study was of a small cohort from a single training region, but provides a potential model for future studies to repeat a similar analysis using national training data sets. Similarly, Abdelrahman *et al.*[52] have examined the relationship between volume of operative experience and level of competence achieved in a small cohort from a different, single geographical area of training, reporting that curriculum requirements do not accurately reflect the numbers of operations required for competency. Such further studies examining the relationship between operative experience and competency will help to inform the future setting of minimum operative experience requirements.

This systematic review and meta-analysis has identified a lack of studies describing the operative experience of general surgery trainees, particularly outside of the USA. It has highlighted the variation in the operative experience of newly qualified general surgeons worldwide, and described the differences in surgical training systems in countries with published general surgery trainee operative experience data. Setting of UK curriculum operative experience requirements could be informed by future studies of the relationship between operative experience and competency assessments.

Acknowledgements

The authors acknowledge the contribution of J. Grogan (Research Support Librarian, University of Nottingham) to the study. This work was funded by a Royal College of Surgeons of Edinburgh Clinical Research Fellowship awarded to E.J.E. The funders had no role in the design of the study, the collection, analysis and interpretation of data, writing of the article and the decision to submit it for publication. D.J.H. is funded by a National Institute for Health Research Post-Doctoral Fellowship.

Disclosure: The authors declare no conflict of interest.

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Supporting information
Additional supporting information may be found in the online version of this article:

Table S1 Ovid MEDLINE search strategy (Word document)

Typesetter: please refer to marked-up figures

Fig. 1 PRISMA diagram showing selection of articles for review

Fig. 2 Meta-analysis of total operations performed during general surgery training. Mean values are shown with 95 per cent confidence intervals

Table 1 Study demographics

Reference	Country	Years included*	Data geography	Data source	Total no. of trainees†	Exclusions	Aims	Data presented (for full cohort)	Data descriptions
Thomas *et al.*[24]	UK	2012–2013	National	eLogbook	155	n.s.	Comparison with curriculum requirements	Total and procedure-specific	Median, i.q.r., range
Allum *et al.*[14]	UK	2010–2011	National	eLogbook	58	LTFT, OOPP	Description of operative experience	Procedure-specific	Mean, median, range
Hopmans *et al.*[40]	Netherlands	2005–2012	Regional	Hospital records	64	LTFT, OOPP, area transfer	Analysis of impact of hours restrictions	Total operations	Mean, range, s.d.
Serra-Aracil *et al.*[41]	Spain	2009	National	Online logbook	64	n.s.	Description of operative experience	Total operations	Mean
Aphinives[18]	Thailand	2011–2012	National	Online logbook	162	LTFT, area transfer, non-completers	Description of operative experience	Total and procedure-specific	Mean, median, range
Malangoni *et al.*[25]	USA	2005, 2010–2011	National	ACGME	2945	n.s.	Analysis of impact of curriculum introduction	Total and procedure-specific	Median
McCoy *et al.*[26]	USA	2000–2011	National	ACGME	-	n.s.	Analysis of MIS operative experience	Procedure-specific	Mean
Hanks *et al.*[19]	USA	2009	National	ACGME	976	n.s.	Analysis of impact of fellowship trainee	Procedure-specific	Mean
Eckert *et al.*[27]	USA	2002–2008	Local	Hospital records	17	n.s.	Description of operative experience	Total and procedure-specific	Mean, range, s.d.
		1999, 2008	National	ACGME	2005	n.s.			
Sachs and Pawlik[28]	USA	1999–2012	National	ACGME	-	n.s.	Description of operative experience	Total operations	Median
Neville *et al.*[29]	USA	2002–2011	Local	ACGME	47	n.s.	Analysis of MIS operative experience	Procedure-specific	Mean
		2000–2011	National	ACGME	-	n.s.			
Unawane *et al.*[30]	USA	1997, 2010	National	ACGME	-	n.s.	Analysis of MIS operative experience	Procedure-specific	Mean
Fryer *et al.*[20]	USA	2007–2009	Local	ACGME	15	n.s.	Comparison with curriculum requirements	Total and procedure-specific	Mean, s.d.
Carson *et al.*[31]	USA	2000–2008	National	ACGME	9067	n.s.	Analysis of MIS operative experience	Total and procedure-specific	Mean
Alkhoury *et al.*[32]	USA	1999–2008	National	ACGME	-	n.s.	Analysis of MIS operative experience	Procedure-specific	Mean
Simien *et al.*[33]	USA	1998–2008	National	ACGME	6049	n.s.	Analysis of impact of hours restrictions	Total operations	Mean
Kairys *et al.*[34]	USA	1992–2006	National	ACGME	-	n.s.	Analysis of impact of hours restrictions	Total operations	Mean
Bell *et al.*[21]	USA	2005	National	ACGME	1022	n.s.			

		2006			805		Description of operative experience	Total and procedure-specific	Mean, range, s.d.
Damadi *et al.*[35]	USA	2001–2005	Local	ACGME	17	n.s.	Analysis of impact of hours restrictions	Total operations	Mean
Bland *et al.*[36]	USA	1998–2004	National	ACGME	-	n.s.	Analysis of impact of hours restrictions	Total operations	Mean
Chung *et al.*[22]	USA	1994–2001	National	ACGME	4968	n.s.	Analysis of MIS operative experience	Total and procedure-specific	Mean
Parsa *et al.*[37]	USA	1991–1997	National	ACGME	7036	n.s.	Description of operative experience	Procedure-specific	Mean
Libermanand Greason[38]	USA	1992–1996	Local	Hospital records	-	n.s.	Analysis of MIS operative experience	Total and procedure-specific	Mean
Schoetz[39]	USA	1991–1996	National	ACGME	6020	n.s.	Description of operative experience	Procedure-specific	Mean

*Range of years with data or individual years. †Sum of all trainees with data presented in the study. n.s., Not stated; LTFT, Less than full time training; OOPP, Out of Programme Period; ACGME, Accreditation Council for Graduate Medical Education MIS, minimally invasive surgery.

Table 2 Total operations per graduating trainee

Reference	Country	Years included	Endoscopy	Total no. of trainees*	Total no. of operations†
Thomas *et al.*[24]	UK	2012–2013	Excluded	155	1802‡,1844¶
Allum *et al.*[14]	UK	2010–2011	Excluded	58	1876‡¶, 1915¶
Hopmans *et al.*[40]	The Netherlands	2005–2012	Excluded	64	1291–1490
Serra-Aracil *et al.*[41]	Spain	2009	Unknown	64	1325‡
Aphinives[18]	Thailand	2011–2012	Excluded	162	783#
Sachs and Pawlik[28]	USA	1999–2012	Excluded	–	903–976‡
Malangoni *et al.*[25]	USA	2005, 2010–2011	Included	2945	1023–1238‡
Fryer *et al.*[20]	USA	2007–2009	Excluded	15	882–1103
Eckert *et al.*[27]	USA	1999, 2008	Excluded	2005	914–966
Carson *et al.*[31]	USA	2000–2008	Excluded	9067	879–942
Bell *et al.*[21]	USA	2006	Included	805	1264
Simien *et al.*[33]	USA	1998–2008	Excluded	6049	900–967
Kairys *et al.*[34]	USA	1992–2006	Excluded	–	900–967
Damadi *et al.*[35]	USA	2001–2005	Excluded	17	925–1412
Bland *et al.*[36]	USA	1998–2004	Excluded	–	930–966
Chung *et al.*[22]	USA	1994–2001	Excluded	4968	924–962
Liberman and Greason[38]	USA	1992–1996	Excluded	–	1197–1233§

*Sum of all trainees with data presented in the study. †Range of averages, rounded to nearest whole procedure for the years included in the study; values are mean, except ‡median and §not stated. ¶Calculated from raw data; #provided by author.

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Table 3 Procedure-specific data

Reference	Country	Years included	Total no. of trainees*	Total no. of procedures†			
				Appendicectomy	Hernia repair	Cholecystectomy	Colectomy
Thomas *et al.*[24]	UK	2012–2013	155	121‡	92‡	103‡	42‡
Allum *et al.*[14]	UK	2010–2011	58	–	90	96	33
Aphinives[18]	Thailand	2011–2012	162	73	18	6¶	5
Malangoni *et al.*[25]	USA	2005, 2010 - 2011	2945	46–60	60–70	103–118	52–59
McCoy *et al.*[26]	USA	2000–2011	–	40–62	59–71	100–116	46–60
Unawane *et al.*[30]	USA	1997, 2010	–	32–59	59–67	91–118	40–60
Hanks *et al.*[19]	USA	2009	976	63	–	106¶	58
Fryer *et al.*[20]	USA	2007–2009	15	–	113	94¶	42
Eckert *et al.*[27]	USA	1999, 2008	2005	–	59–60	–	57–69
Neville *et al.*[29]	USA	2000–2011	–	39–62	–	–	–
Carson *et al.*[31]	USA	2000–2008	9067	39–54	59–61	–	–
Alkhoury *et al.*[32]	USA	1999–2008	–	39–54	59–61	–	50–57
Bell *et al.*[21]	USA	2005	1022	–	59	88¶	52
Chung *et al.*[22]	USA	1994–2001	4968	–	–	66§¶	–
Parsa *et al.*[37]	USA	1991–1997	7036	31	53–54	59–91	34–39
Liberman and Greason[38]	USA	1992–1996	–	–	–	86–113§	–
Schoetz[39]	USA	1991–1996	6020	–	–	–	34–37§

*Sum of all trainees with data presented in the study. †Range of averages, rounded to nearest whole procedure for years included in the study; values are mean, except ‡median and §not stated. ¶Laparoscopic cholecystectomy data only.

Table 4 Estimated total operations per trainee per year of training

Country	Study dates	Total no of trainees*	Total no. of operations per trainee†	Length of training (years)	Total no. of operations per trainee per year‡
UK[24]	2012–2013	155	1844	6	307
UK[14]	2010–2011	58	1915	6	319
The Netherlands[40]	2005–2012	64	1391	6	232
USA[27]	2008	1020	914	5	183
Thailand[18]	2011–2012	162	783	4	196

*Sum of all trainees with data presented in study. †Means, rounded to nearest whole procedure.
‡Total no. of operations/length of training.