Title: Comparative outcomes of resident versus attending performed surgery: a systematic review and meta-analysis

Author list: Nigel D'Souza[1], Daniel A. Hashimoto[2], Kurinchi Gurusamy[3], Rajesh Aggarwal[4]

Corresponding Author:
Nigel D'Souza, MBBS, MEd
mrnigeldsouza@gmail.com
[1]Registrar in General Surgery, Wessex Deanery, UK
Department of General Surgery, Queen Alexandra Hospital, Southwick Hill Rd, Portsmouth, Hampshire PO6 3LY, UK
Telephone: +44-7748-496-286
Fax: +44-239-228-6263

Daniel A. Hashimoto, MD, MTR
dahashimoto@partners.org
[2]General Surgery Resident, Massachusetts General Hospital, Boston, USA

Kurinchi Gurusamy, MBBS, PhD
k.gurusamy@ucl.ac.uk
[3]Lecturer in Surgery, UCL Medical School, London, UK

Rajesh Aggarwal, FRCS, PhD
rajesh.aggarwal@mcgill.ca
[4] Associate Professor of Surgery. Director, Steinberg Centre for Simulation and Interactive Learning, Faculty of Medicine, McGill University

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Abstract

Objective: To determine whether outcomes are different when surgery is performed by resident or attending surgeons, and which variables may affect outcomes.

Design: MEDLINE, EMBASE and the Cochrane Library were searched from inception to May 2014 alongside the bibliographies of all included or relevant studies. Any study comparing outcomes from surgery performed by resident versus attending surgeons was eligible for inclusion. The main outcome measures were surgical complications (classified by Clavien-Dindo grade), death, operative time and length of stay. Data was extracted independently by two authors and analysed using the random-effects model.

Results: The final analysis included 182 eligible studies that enrolled 141 555 patients. Resident-performed surgery took longer by 10.2 minutes (95% CI 8.38 to 11.95), and had more Clavien-Dindo grade 1 (Rate Ratio 1.14, 95% CI 1.02 to 1.29) and grade 3a complications (Rate Ratio 1.22, 95% CI 1.04 to 1.44). Resident performed surgery resulted in fewer deaths (Risk Ratio 0.83, 95% CI 0.70 to 0.999) with a shorter length of stay of -0.49 days (95% CI -0.77 to -0.21). Significant heterogeneity was present in 7 out of 10 outcomes, which persisted during multiple subgroup analyses.

Conclusions: Resident performed surgery appears to be safe in carefully selected patients. The significant amount of heterogeneity present in the study outcomes prevents generalisability of these results to specific clinical contexts.

Keywords: surgical education, surgical procedures, treatment outcomes, professional competence, patient safety

ACGME competencies addressed: Practice Based Learning

Introduction

Patient safety lies at the heart of the conflict between surgical training and healthcare provision. Future surgeons still predominantly train under the traditional model of apprenticeship, where residents perform progressively complex surgery under the supervision of attending surgeons.

Understanding the implications of resident performed surgery is of paramount importance as autonomy in the operating room comes under increasing threat. Publication of surgeon specific outcomes in the United Kingdom and recently the United States [1-3] has led to the national press naming attendings with worse outcomes [4, 5]. Guidelines in the USA (Health Care Financing Administration and Centers for Medicare and Medicaid Services reimbursement guidelines) stipulate that attendings be present and scrubbed for all “critical” portions of a procedure regardless of the nature/complexity of the procedure. In the UK, the National Emergency Laparotomy Audit [6] recommends that attendings directly supervise all high risk cases.

However, being present and scrubbed does not necessarily mean attendings must perform the operation; rather, they must provide a level of supervision appropriate for the experience and ability of the resident. In the face of the additional challenges such as financial pressures to reduce operative times, duty hour restrictions, and reimbursement incentives, attendings are charged with protecting operative opportunities and training the next generation of surgeons. Data demonstrating outcomes from resident-performed surgery could impact the practice patterns of supervising surgeons in the degree of autonomy granted to residents. As 230 million operations are conducted annually worldwide [7], it is essential to stakeholders, including patients, resident and attending surgeons, hospitals, medical educators, certification boards, surgical associations, healthcare systems and policy makers, and taxpayers, that surgeons in training produce safe outcomes.

While hundreds of studies comparing resident versus attending performed surgery have been published in the literature across multiple surgical specialties, there have been conflicting results. These include multiple studies that have analysed data on hundreds of thousands of patients in the American National Surgical Quality Improvement Program (NSQIP), which report that resident involvement in surgery is either safe [8], unsafe [9-11], or has significantly more minor morbidity of unknown clinical significance [12-14]. No comprehensive meta-analysis looking at all surgical procedures across multiple surgical specialties has been performed to date.

The objective of this systematic review and meta-analysis was to investigate whether surgery performed by resident or attending surgeons has equivalent outcomes.

Methods

This study was conducted in adherence to PRISMA standards [15]. The review protocol was registered with the PROSPERO International Prospective Register of Systematic Reviews (ref. CRD42013003540 at http://www.crd.york.ac.uk/PROSPERO) on January 2nd 2013.

Study Selection

The search strategy was designed by the authors (ND'S, DH, RA) with advice from a research librarian. MEDLINE, EMBASE and the Cochrane Library were searched from inception until May 2014. Our search terms comprised a combination of keywords and MESH terms that included but were not limited to health care quality, patient care, complications, attending or consultant or trainee or resident and surgery (see eTable1 in the Supplement for full search terms). The search was supplemented by manually-searching the bibliographies of included or otherwise relevant publications.

Any study that compared clinical outcomes such as mortality, morbidity, operative time and length of stay resulting from surgery performed by resident versus attending surgeons was eligible. Randomised, prospective or retrospective observational study designs were all included. Case reports, reviews or letters, abstracts and conference proceedings were not included.

Two authors (ND'S and DH) independently screened the titles and abstracts and obtained full texts for references potentially meeting the inclusion criteria. The final decision about inclusion was made based on the full text. Conflicts about full text inclusion were resolved after discussion with the supervising author (RA).

Data Extraction

Data was extracted into a Microsoft Excel (Microsoft Corp., Redmond, WA) data extraction form by two authors (ND'S and DH) independently. Data on study demographics, study design, level of resident participation, level of supervision, and risk of bias was collected. Outcome measures included mortality, morbidity, operative time, length of hospital stay and conversion to open surgery for minimally invasive procedures.

To classify the range of post-operative morbidity from procedures across all surgical specialties, the Clavien-Dindo (CD) Classification tool [16, 17] was utilised. For continuous outcomes, imputation of mean and standard deviation values was performed as per Cochrane Handbook guidelines [18].

Risk of Bias

Domain-based assessment was utilized to determine risk of bias based on recommendations from the Cochrane Collaboration[18]. The following 6 domains were evaluated: (1) selection bias (if resident or attending surgeons operated on different groups of patients e.g. attending surgeons operated on patients with more comorbidities); (2) performance bias (if clinicians providing post-operative care were not blinded to the identity of the operating surgeon); (3) detection bias (if clinicians performing assessment of outcomes were not blinded to the identity of the operating surgeon); (4) attrition bias (if patients who met the inclusion criteria were excluded from the analysis); (5) selective reporting bias (if studies did not report important clinical outcomes); (6) other bias (this included independent assessment of resident participation, grading of technical difficulty of procedure, quantification of attending expertise and quantification of resident experience).

Data Analysis

Data was analysed using Stata Intercooled version 11. Risk ratio (RR) with 95% confidence intervals (CI) was calculated for death and conversion to open surgery (binary outcomes). Rate ratio (RaR) with 95% CI were calculated for the CD grade I to IV complications (count outcomes) since the same patient may develop more than one complication. Mean difference (MD) with 95% CI were calculated for operating time and length of hospital stay (continuous outcomes). Data was meta-analysed using DerSimonian & Laird method for binary outcomes [19] and generic invariance method for count and continuous outcomes to calculate the summary effect estimate with 95% CI. Heterogeneity was assessed by calculating Chi^2 test and Higgin's I^2 [20] for heterogeneity. To investigate sources of heterogeneity in patient outcomes, subgroup analyses were planned in the following areas: surgical speciality, study region, study design (randomised controlled trials, prospective studies, retrospective studies), resident year, attending surgeon experience, and level of supervision. Publication bias was assessed by visual inspection of funnel plot and by Egger's test[21].

Three sensitivity analyses were performed to investigate whether the results of the meta-analysis were affected by methodological decisions. The first sensitivity analysis excluded biased studies that were significant outliers on the forest plot, where methodological flaws led to their significantly different effect estimate. The second sensitivity analysis excluded studies in which the mean and/or standard deviation was imputed for operating time and length of hospital stay. The third sensitivity analysis included data from NSQIP. NSQIP studies were not included in the main analysis because they only specify whether residents were “involved” in the surgery, not whether they assist or perform the operation under supervision.

Results

Study Flow

Out of a total of 3597 citations identified by the search strategy, 182 studies met the inclusion criteria. The reference flow is shown in figure 1. The full reference list of included studies can be found in the eReference list in the Supplement.

Study Characteristics

Data was extracted for 288 operative procedures from 182 studies. A total of 141 555 patients were enrolled in all studies included in the main analysis. Mean patient age was 56.8 years (range 2 to 77), and 36% of patients were female. Residents performed 35% of surgeries. When NSQIP studies were included in the sensitivity analysis, the number of patients rose to 1 952 305. However, the same patients from the NSQIP database may have been included in different NSQIP studies.

Fifty-four studies (30%) were conducted in North America, 50 (27%) in Europe and 44 (24%) in the UK. The remaining 34 (19%) of studies were conducted in Asia, Africa, the Middle East or were multi-regional studies (see eTable 2 in the Supplement).

General surgery was investigated in 91 (50%) studies, cardiac surgery in 31 studies (17%), and vascular surgery in 12 studies (7%). The remaining 48 (26%) of studies were conducted across other surgical specialties (see eTable 2 in the Supplement).

Main results

Resident-performed surgery led to significantly more minor, self-limiting complications (CD grade 1, RaR 1.14, 95% CI 1.02 to 1.29), more complications that required intervention without general anaesthetic (grade 3a, RaR 1.22, 95% CI 1.04 to 1.44), and longer operative times (MD 10.2 minutes, 95% CI 8.39 to 11.95). However, surgery by residents resulted in significantly fewer deaths (RaR 0.80, 95% CI 0.67 to 0.96), and a shorter length of stay (MD -0.52 days, 95% CI -0.81 to -0.24). There was no statistically significant difference in minor complications requiring antibiotics (grade 2, RaR 0.91, 95% CI 0.74 to 1.12), need for intervention under general anaesthetic (Grade 3b, RaR 0.98, 95% CI 0.88 to 1.1), single (grade 4a, RaR 0.89, 95% CI 0.79 to 1) or multi-organ failure (grade 4b, RaR 0.68, 95% CI 0.32 to 1.46), or conversions (RaR 0.92, 95% CI 0.75 to 1.13). These results can be seen in table 1, and forest and funnel plots in eFigures 1-20 in the Supplement.

Table 1: Main Analysis Results

Outcomes	No. of studies	No. of patients	**RaR/RR/WMD**	*p*	**Heterogeneity**			**Publication Bias**
					Chi²	*p*	**I²**	**Egger's**
CD Grade 1	**51**	**23607**	**1.14** [a] (1.02 to 1.29)	**0.027**	56.72	0.24	11.8%	p=0.80
CD Grade 2	66	46175	0.91 (0.74 to 1.12)	0.365	**273.98**	**<0.01** [c]	**76.3%** [c]	p=0.19
CD Grade 3a	**36**	**18183**	**1.22** [a] (1.04 to 1.44)	**0.017**	27.96	0.80	0.0%	**p<0.01** [d]
CD Grade 3b	94	90340	0.98 (0.88 to 1.10)	0.734	**118.74**	**0.04** [c]	21.7%	**p<0.01** [d]
CD Grade 4a	41	66767	0.89 (0.79 to 1.00)	0.050	**58.69**	**0.03** [c]	31.8%	p= 0.22
CD Grade 4b	3	3326	0.68 (0.32 to 1.46)	0.413	1.77	0.41	0.0%	p=0.46
Death	**62**	**95668**	**0.80** [b] (0.67 to 0.96)	**0.018**	**121.40**	**0.01** [c]	49.8%	p=0.11
Conversions	34	15519	0.92 (0.75 to 1.13)	0.431	**52.82**	**0.02** [c]	37.5%	p=0.10
Operative Time Difference (minutes)	**97**	**72233**	**10.2** [a] (8.38 to 11.95)	**<0.001**	**1082.49**	**0.01** [c]	**91.1%** [c]	**p=0.01** [d]
Length of Stay (days)	**48**	**35286**	**-0.52** [b] (-0.81 to -0.24)	**<0.001**	**240.91**	**0.01** [c]	**80.5%** [c]	p=0.07

[a] resident outcomes significantly worse [b] resident outcomes significantly better, [c] significant amount of heterogeneity (Chi² *p*<0.05, I²>50%), [d] significant amount of publication bias. Parentheses indicate 95% confidence intervals.

There was evidence of heterogeneity detected by Chi-square test (p<0.05) in 7/10 outcome measures, and substantial (>50%) heterogeneity was confirmed by I-squared test in 3/10 outcomes (table 1). There was evidence of publication bias detected by Egger's test (p<0.05) in 3/10 outcomes (table 1).

Subgroup analysis

Across every subgroup analyses, resident outcomes varied without consistency in the direction of the effect estimates due to heterogeneity. No explanatory variables such as surgical speciality, study region, study design, resident year, attending surgeon experience or level of supervision had a significant effect on resident outcomes. All subgroup results can be seen in eTables 3-8 in the Supplement.

Sensitivity Analyses

Results of the three sensitivity analyses are summarized in table 2 (see eTables 9-11 in the Supplement for full results).

Table 2: Statistically significant results in the sensitivity analyses

Main analysis	More grade 1 resident complications	More grade 3a resident complications	Fewer resident deaths	Longer resident operative times	Shorter resident hospital stay
Sensitivity Analysis 1 (no outliers)	More grade 1 resident complications		Fewer resident deaths	Longer resident operative times	Shorter resident hospital stay
Sensitivity Analysis 2 (no imputed mean/sd operating time or hospital stay)	N/A	N/A	N/A	Longer resident operative times	Shorter resident hospital stay
Sensitivity Analysis 3 (including NSQIP studies)			Fewer resident deaths	Longer resident operative times	

Resident performed surgery remained safe and ceased to have more CD grade 3a complications (RaR 1.11, 95% CI 0.93 to 1.33) in the first sensitivity analysis which excluded methodologically weak studies with outlying results.

After excluding studies where the mean and standard deviation for operating times and length of stay was imputed, residents still had longer operative times (MD 8.65 minutes, 95% CI 6.05 to 11.24) and shorter length of stay (MD -0.52 days, 95% CI -0.99 to -0.06) in this analysis.

When NSQIP data was included, resident performed surgery ceased to have more grade 1 and 3a complications. The only statistically significant differences between resident and attending outcomes were fewer resident deaths (RaR 0.84, 95% CI 0.77 to 0.93) and longer resident operative times (MD 15.08 minutes, 95% CI 13.57 to 16.59).

Study Quality

Extensive bias was present in the data (table 3), particularly selection bias.

Table 3: Risk of Bias Summary

Type of Bias	Present in studies	
Selection	172	95%
Performance	181	99%
Detection	176	97%
Attrition	19	10%
Selective reporting	15	8%
Other	182	100%

Explicit case allocation by attending surgeons of technically easier or less sick patients to residents was described in 63 (34.6%) studies. Processes to eliminate selection bias were not described in 109 (59.9%) studies. Attrition and selective reporting bias was low, but performance and detection bias were present in nearly all studies.

All studies had additional forms of bias that prevent case comparability. No study differentiated the technical difficulty of each operation. No study had an independent observer to accurately assess resident participation or attending takeover of the case. Attending surgeon's operative expertise (subspecialisation, volume) was frequently not quantified, and expertise in surgical training was never described.

There was evidence of publication bias in several outcomes suggesting that there may be other studies that have not been published because of their results.

Discussion

On the basis of this study, for appropriately selected cases, resident performed surgery does not result in a greater number of major complications or mortality than attending surgeons.

In the main analysis, residents had significantly more CD grade 3a complications (requiring intervention but not under a general anaesthetic) and grade 1 complications (minor deviation from post-operative course). However residents ceased to have significantly more grade 3a complications after excluding outlying studies with significant bias.

Most resident-caused grade 1 complications were self-limiting with low risk of long term sequelae. These included: nausea and vomiting, atelectasis, increased analgesia requirements, electrolyte abnormalities, haematomas, seromas, and urinary retention.

Unsurprisingly, resident performed operations were longer as they usually have not acquired the same level of cognitive or psychomotor skills as attending surgeons [22, 23]. The mean additional operating time for residents is 11 minutes; it is unlikely that this short increase in operative time increases patient morbidity as has been reported with prolonged surgery [24, 25].

Selection bias was present in 94.5% of studies and explains the lower mortality and length of stay of resident performed surgery. Operations are designated as training cases after careful selection of patients with lower anaesthetic risk and less complicated disease[26, 27] by attendings. Similarly, the shorter length of stay after resident performed surgery may be due to residents operating on lower risk patients. The majority (64%) of resident surgeries were explicitly described as being performed under supervision. However no difference in outcomes on subgroup analysis (see eTable 8 in the Supplement) was found for unsupervised resident performed surgery, implying that residents were allowed to operate independently on selected cases upon accruing enough experience and expertise.

The multiple sources of bias identified in this analysis precluded case comparability, caused further heterogeneity of results, and prevented a more conclusive interpretation of the data. Clinical outcomes were examined in most studies, resulting in low selective reporting bias and attrition bias due to the limited period of follow up. However, since most trials were neither prospective nor funded to employ blinded observers, the post-operative healthcare providers who assessed outcomes were aware of the identity of the operative surgeon and consequently performance and detection bias was present in nearly all studies. The absence of intra-operative observers also prevents rigorous assessment of the level of resident participation and attending takeover during surgery.

We utilised random-effects meta-regression to investigate the multitude of explanatory variables that link resident performed surgery to patient outcomes and allow for residual heterogeneity. Despite this, heterogeneity persisted due to clinical and methodological diversity, extensive bias, and omitted data on variables that impact on patient outcomes. Poor peri-operative care leading to failure to rescue will affect patient outcomes[12, 28], but data on this and many other hospital, patient or disease-specific variables was rarely available in the included studies. Consequently, heterogeneity persisted throughout these subgroup analyses which found no consistent effect on outcomes due to surgical speciality, study region, study design, resident year, attending surgeon experience or level of supervision.

While controlling for all possible confounders would be unrealistic, our analyses highlight the importance of establishing clinical trial collaboratives or guidelines for standardized collection of data to better understand patient outcomes in resident-performed surgery.

Limitations

We excluded NSQIP studies from the main results due to their methodological limitations. NSQIP studies assume that surgical outcomes are affected by resident involvement because of their active participation in the case. However, this assumption is fundamentally spurious as the extent of resident participation is not evaluated. Non-NSQIP studies make the distinction between resident assisted surgery and supervised resident performed surgery. The exact extent of resident participation is still difficult to assess and remains a potential source of bias. However as in real life, attending input into a supervised resident operation will vary on a case by case basis.

As a registry study design, NSQIP uses case-matching to create its equivalent resident and attending cohorts, despite scepticism over the ability of these techniques to eliminate all unobserved confounders[8, 12]. Many cardiac surgery studies similarly report that prognostic scoring systems e.g. Euroscore, Parsonnet[29-33] will not account for case difficulty due to patient and disease factors that cannot be quantified, such as coronary anatomy.

CD classification enabled complications to be categorised across a wide range of specialties and procedure, although none of the included studies used this system. Not all complications could be reliably captured due to incomplete information in the study data. Complications were categorised in some studies by the organ system affected (e.g. cardiac) without indicating the severity of the complication[34-36]. Similarly, complications were frequently described without information on their potentially different treatment options, e.g. a post-operative collection may be a grade 2, 3a or 3b complication (treatment with antibiotics, percutaneous drainage or surgery). Finally, the grade of complication may not reflect its impact on a patient’s quality of life, e.g. intractable chronic pain vs. reversible renal failure treated with renal replacement therapy. Complications should be classified based on the impact it has on patients – both in the short-term and in the long-term – rather than simply on the basis of requirement for further interventions or the use of resources such as the intensive care unit.

Resident postgraduate year designation was not consistent across study locations, due to different postgraduate entry points into specialist surgical training. One final limitation of the data was the limited period of follow up in the studies which likely led to under-reporting of complications, as post-operative mortality may continue to be high beyond 30 days [37, 38].

Generalisability of conclusions

The methodology of the included studies resulted in considerable bias and heterogeneity, but also reflect the outcomes of real-world surgical training. Resident performed surgery was safe in selected patients, with significantly more minor complications and longer operative times but fewer deaths and a shorter length of stay. This is consistent with the results of a recent meta-analysis of colorectal resections [39] and a systematic review of resident performed surgery [40]. These studies also reported significant heterogeneity [39], preventing meta-analysis in one study[40].

The inconsistency of these results prevents generalisability of the findings of this meta-analysis to specific clinical contexts; thus, no conclusions could be made to determine the patient profile or type of operation that is optimal for safe resident performed surgery. However, the nature of the bias present in the studies can still be illuminating. Selection bias (in 95% of studies) suggests that the vigilance of attending surgeons to select the appropriate case and level of supervision ensures patient safety. Careful case selection can challenge residents appropriately and develop their skills without putting patients at risk, including technically challenging procedures usually performed during fellowship training, such as laparoscopic anterior resection [41, 42], laparoscopic prostatectomy [43] or laparoscopic Roux-En-Y gastric bypass [44] with equivalent outcomes.

Future research guidelines

The question of how to optimally train surgeons, whilst protecting patient safety remains unanswered. The impact of an individual variable such as trainer experience is obscured by the melee of other identified and hidden variables that affect patient outcomes in surgical training. Research in medical education has traditionally focused on educational rather than patient outcomes, and qualitative analysis may offer a starting point to identify and unpack important factors. However, both educators and policy makers need to know which training factors optimise patient outcomes to fund and guide future training. This cannot be achieved without standardisation of research methods to conduct rigorous quantitative studies oriented to patient outcomes. To achieve a successful meta-analysis, future primary studies should adjust using validated measures of case-mix adjustment, use patient-oriented outcomes, and follow appropriate reporting guidelines such as the CONSORT [45] or STROBE guidelines [46]. Particular attention should be paid to sources of bias unique to surgical training: technical difficulty of each operation, technical and teaching expertise of attending surgeons, and clarification of the extent of participation of attending surgeons in resident performed surgery.

Conclusion

Resident-performed surgery appears to be safe in carefully selected patients. Despite the large number of patients included in this meta-analysis, the considerable heterogeneity present in the study outcomes means the results may not be generalised to specific clinical contexts.

Figure 1: PRISMA Flow Diagram

Acknowledgements:

Author Contributions: Nigel D'Souza (ND'S), Daniel Hashimoto (DH), Kurinchi Gurusamy (KG), Rajesh Aggarwal (RA)

Study concept and design: RA, ND'S, KG

Acquisition of data: ND'S, DH

Analysis and interpretation of data: ND'S, DH, RA, KG

Drafting of the manuscript: ND'S, RA, KG

Critical revision of the manuscript and final approval: ND'S, DH, RA, KG

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