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Surgeon burnout, impact on patient safety and professionalism: A systematic review and meta-analysis

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Background

Rates of burnout in surgeons are high [1]. Burnout is comprised of two main facets: exhaustion, feelings of work-related weariness and depersonalisation or disengagement, where professionals experience detachment from their work or patients [2]. A recent multi-specialty systematic review in surgeons found that up to 31% of attending surgeons and 42% of resident surgeons experience high emotional exhaustion, and high depersonalisation is reported by up to 26% of attending and 53% of resident surgeons [1].

Systematic reviews of broader healthcare groups suggest that higher healthcare professional burnout is consistently linked with poorer patient safety and quality of care [3,4]. A systematic review of 47 studies and including 42,473 physicians reported that high burnout was associated with a greater risk of being involved in patient safety incidents [5]. Individual studies in surgeons have suggested that this pattern may also be present in surgical groups specifically [6-8], but as no systematic review has sought to aggregate and synthesise these findings, the nature and strength of this association is currently unclear. Understanding this relationship is important for surgeon leaders and healthcare managers when identifying healthcare policy priorities. If present and significant, this association would suggest that tackling surgeon burnout may be a priority not only for supporting the surgical workforce but also for improving the safety and quality of patient care.

In order to address these gaps, the present review aimed to conduct a systematic review and meta-analysis of studies that investigated the association between surgeon burnout and 1) patient safety and/or 2) surgical professionalism.

Methods

The protocol for the systematic review was prospectively registered on PROSPERO (registration number: CRD42019136947). The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [9].

Search Strategy

The following databases were searched for relevant literature from inception to February 2021: PsycINFO, Ovid MEDLINE(R), EMBASE, Cochrane Database, CINAHL, and Web of Science (Supplementary file, Appendix A). Reference lists of relevant studies were manually scanned for other related studies. The search terms were informed by previous similar reviews [5,10], and our search strategy involved combinations of three blocks of terms (burnout, physician or surgeon and patient safety or professionalism) using a combination of text

words and medical subject headings (MeSH terms; Appendix A). The specificity of the search strategy was tested by checking whether it identified a set of eight relevant papers previously identified through non-systematic searches.

Eligibility Criteria

Studies meeting the following criteria were included (Supplementary file, Appendix B):

- **Research population:** Surgeons, including but not restricted to general surgeons, plastic surgeons, urology surgeons and transplant surgeons.
- **Condition/exposure studied**: Burnout syndrome, which is characterised by depersonalisation or disengagement, emotional fatigue and lack of personal satisfaction resulting from increased work-related stress [11].
- **Outcomes**: Outcomes pertaining to patient safety and aspects of professionalism, like ethical practice, empathy, and emotional restraint as types of professionalism, were considered.
- **Study Design:** Quantitative research studies including those with a cross-sectional/prospective/longitudinal design.
- **Context:** Studies in any context were considered.

Studies were excluded if they:

- Investigated psychological stress, depression or anxiety only and did not include a measure of burnout.
- Were published in languages other than English.
- Were a conference paper or grey literature.
- Included surgeons as part of a wider participant group of doctors and the data on surgeons specifically was not reported or provided following email request.

Study selection

We exported the search results from the five databases to an Excel sheet after removing all duplicates. The selection process involved two stages: the first was the title and abstract screening, and the second was the full text screening. Two authors (TG and AD) independently screened 10% of titles during these two stages. The interrater reliability during both stages was high (K = 0.89 and 0.91, respectively) and any disagreement was resolved through discussion with JJ. All the remaining abstract and full text screening was completed by TG.

Data extraction

A data extraction sheet included the following items:

- Study characteristics—year, number of participants, research design and country
- Participant characteristics—length of service, age and gender
- Measurement of burnout
- Patient safety variable
- Patient professionalism variable (Supplementary file, Appendix C).

Two authors (TG and KH) extracted 20% of the studies to check for agreement. All the remaining data extraction was completed by TG.

Ten studies included surgeons as part of a wider participant group of doctors. We contacted these authors and asked them if they could provide the data for surgeon participants alone, rather than the whole data set. Six study authors responded that they could not provide these data [8,12-16], and two study authors did not respond [17-19], so these studies were excluded. One of the ten studies provided the data of surgeons, so we included it in this review [20].

Quality assessment and risk of bias

As studies included in the review did not test interventions but instead assessed the presence of associations, we used an adapted version of the Cochrane Risk of Bias tool [21] along with additional categories to assess the reliability and validity of the measures used[10]. These criteria have seven elements: Representativeness, Randomisation, Blinding, Measures of patient safety, Measures of burnout, Confounding variables and Power and effect sizes (see Supplementary file, Appendix D).

Each article was assessed using the quality assessment tool (see appendix F), and all articles were then summarised together to give an overall quality score. Two reviewers (TG, KH) independently undertook 10% of the risk of bias assessment, the interrater agreement Kappa was high 0.98, and the remaining coding was completed by TG.

Analyses

The main analyses synthesised the overall effect size for the association between surgeon burnout and patient safety across all included studies. Odds ratios (ORs) and 95 percent confidence intervals (CIs) were used as the index of effect size as these were the most widely recorded effect size across the primary studies. The data were analysed using a

random effects model in Comprehensive Meta-Analysis (CMA)[22]. We used the required transformations in CMA for the various different metrics as suggested by the Cochrane Handbook [21] to obtain ORs where ORs and their standard errors were not recorded in the primary reports. If the OR > 1, this indicated that higher burnout was associated with poorer patient safety outcomes. In contrast, an OR <1 indicated that burnout was associated with better patient safety outcomes. The I^2-statistic and related test-based 95 percent CIs were used to measure heterogeneity. Small, moderate, and high heterogeneity, are represented by I^2 values of 25%, 50%, and 75%, respectively [21]. To measure sensitivity, this study followed Higgins et al's strategy and re-ran the meta-analyses numerous times, deleting one study at a time[21]. Publication bias was examined by exploring the symmetry of funnel plots and the statistical significance of Egger's test [23].

Results

A total of 4,454 articles were identified from the database search, and an additional 19 records were located through hand and citation searching. After the removal of duplicates, 3,160 articles were included in the title and abstract screening phases. 44 articles were retained for full-text screening and 14 articles were included in the final review. Of these, nine were included in the meta-analysis (Figure 1).

Descriptive analysis and study characteristics

Descriptive information for all studies is presented in Table 1. The 14 studies included 27,248 surgeons with a mean age of 38.50 [7,24-31], with five studies not reporting participant age [20,32-35]. Of the studies that were included, 20,349 (74%) surgeons were male, 4,792 (18%) were female [7,24-29,31-33] with four remaining studies not providing gender information [20,30,34,35]. Information regarding surgical specialities is presented in Table 2. Five studies included trainee surgeons[26 36 32 28 37],six studies included practicing surgeons[25,29-31,38,39],and the Klein et al (2010) study include both training and practicing surgeons[33]. In two studies the types of surgeons recruited were unclear[34,35].

In terms of the geographical regions of the studies that were included, nine were from United States [7,24-26,28-30,32,34], four from Europe including France, Germany, Greece and Poland [20,27,33,35,] and one from China [31].

Measurement of burnout

Twelve studies [7,20,24,25,27-32,34,35] measured burnout using some variant of the Maslach Burnout Inventory (MBI)[40], and one study [33] used the Copenhagen Burnout Inventory (CBI)[33].The study by Balch et al. [24] used two items to measure burnout: MBI and two added questions that measure emotional exhaustion and depersonalization. The study by Coombs et al. [26] used the Stanford Professional Fulfilment Index[41] (Table 1).

Patient outcomes

Nine studies focused on patient safety and measured patient safety by asking self-reported questions about whether there had been medical errors with a yes/no response format [24-30,32,33]. One study used standardised questions to evaluate medical errors designed by the authors and pilot tested by 19 surgeons [7], and a final study developed a checklist of medical errors developed by the authors with each item representing a different type of error [35].Six studies measured professionalism, including empathy, loss of temper and patient satisfaction [20,24,30,31,33,34]. One study [20] used the Mehrabian and Epstein Emotional Empathy Scale (EES) [42]. In addition, one study [31] used a questionnaire about loss of temper. This questionnaire was designed by authors to investigate intraoperative irritability, including frequency, possible reasons, consequences, participants' attitude and career satisfaction[31]. The study of Windover et al. (2018) measured patient satisfaction by referring to "Consumer Assessment of Healthcare Providers and Systems surveys" [34]. Two studies measured malpractice; Balch et al. (2011) studied the malpractice issues by asking one question: "Have you gone through a medical malpractice suit in the last two years?"[24] and the study of Soh et al. (2020) used a survey created by the Society for Vascular Surgery that included questions related to medical errors and malpractice litigation[30].

Narrative synthesis: surgeon burnout and professionalism

Four studies found that surgeon burnout was linked to surgeon professionalism [24,30,31,33]. These included one study about the loss of temper, finding that surgeons with high emotional exhaustion were more likely to report losing their temper [31]. Another study found negative correlations between levels of burnout and empathy[20]. In addition, two studies found that malpractice suits were strongly related to burnout [24,30].

One study found higher burnout was significantly associated with poorer perceived quality of care among male but not among female surgeons [33]. In contrast, one study found no link between surgeon burnout and patient satisfaction [34].

Study quality and risk of bias

Figure 2 shows the percentages for each risk of bias item across all studies considered. The highest risk of bias was found for representativeness and randomisation with a 20% risk of bias; next was for was blinding and power and effect size with a 10% risk of bias. Also, only a small number of studies reported the power and effect size. The measure of burnout and confounding had only a 5% risk of bias

Main meta-analysis findings

Surgeon burnout was associated with 2.5-fold increased risk of medical error (OR = 2.51; 95% CI [1.68-3.72]) (Figure 3), but the heterogeneity was high (I^2= 93.62). Eight out of nine of the studies reported a significant relationship between higher surgeon burnout and a greater risk of medical error (Figure 3).

Next the analyses explored the sub facets of burnout. A significant positive association was found between higher levels of emotional exhaustion and a greater likelihood of being involved in a patient safety incident (OR=1.71, 95% [1.35-2.16]) with a moderate amount of heterogeneity (I^2= 66.1 %) (Figure 4-a). There was no significant association (Figure 4-b) between the depersonalisation component of burnout and medical errors (OR= 1.66, 95% CI [0.88-3.11]) with a high level of heterogeneity (I^2=95.84%).

To assess whether the association between burnout and patient safety varied between countries, a sub-group analysis was performed between studies conducted in the United States (k = 6) and studies conducted in other countries (k = 3). The results of these analyses found no significant differences in the magnitude of the burnout-medical error association between these groups of studies (p = 0.85) (see Figure 5). We found a significant association between burnout and medical error in the studies conducted in the United States (OR=2.51; 95%CI [1.53-4.11]) with high heterogeneity (1^2=95.66) and in the studies conducted in other countries (OR=2.33; 95% CI[1.32-4.11]), although heterogeneity was moderate in the latter case (I^2=50.22%).

Sensitivity analysis

As outlined above, we followed Higgins et al's approach and re-ran the meta-analyses multiple times by removing one study at a time to assess sensitivity [21]. We found the odds ratio between surgeon burnout and patient safety varied from 1.32 to 2.23, but remained statistically significant, suggesting the meta-analytic results were not unduly influenced by any individual study. The odds ratio between emotional exhaustion and patient safety varied from 1.48 to 1.98 yet remained statistically significant, implying that no single study altered the meta-analytic results disproportionately. However, for depersonalisation the odds ratio varied from 1.28 to 1.99 but was not statistically in any of the analyses.

Publication Bias

The presence of publication bias was investigated across the nine studies included in the main meta-analysis. Egger's regression test showed that publication bias could have affected the findings (intercept = 4.11, SE = 1.28, $p = 0.007$)[23]. The funnel plot (Figure 6) and Duval and Tweedie's trim and fill analysis revealed that there were no missing studies to the right of the mean; however, there may have been five missing studies to the left of the mean[43]. When the five missing studies were imputed the relationship between surgeon burnout and medical error is no longer significant (OR = 1.35, 95 CI = 0.92 to 1.98).

Discussion

Summary of findings

This review investigated the association between surgeon burnout and 1) patient safety and 2) surgical professionalism. The meta-analytic results indicated that higher burnout was significantly associated with a higher risk of involvement in a medical error. Higher emotional exhaustion was also significantly associated with higher risk of a medical error, but there was no association between depersonalisation and burnout. The results regarding professionalism were too diverse for pooling using meta-analysis, but the narrative synthesis indicated two similar studies linked higher surgeon burnout to poorer surgeon professionalism, which included reduced empathy and loss of temper. Moreover, two studies [24,30] found malpractice suits were strongly related to higher burnout and one study found that surgeon burnout had no significant relationship with the patient satisfaction.

Comparisons with previous reviews

The results outlined in this systematic review are in line with those of previous systematic reviews which indicate that higher burnout is associated with poorer patient safety in physicians and healthcare providers more broadly [10,44-47]. The present findings are also consistent with previous systematic reviews indicating associations between higher burnout and poorer professionalism, as indicated by outcomes such as poorer physician empathy [46]. The present review extends these findings by reporting on these associations in surgeons specifically, which are a group known to report higher levels of burnout than other medical specialties [48].

The question of whether burnout affects medical errors or medical errors affect surgeons is currently unclear. However, there is emerging evidence to suggest that the relationship is likely to be cyclical and bidirectional. For example, a longitudinal study by West et al. (2006) investigated the association between burnout and medical errors in resident doctors and

found that a medical error at one time point was associated with increased burnout at the next time point; similarly, burnout at one time point was associated with greater risk of a medical error at the next time point [49]. More recently, a qualitative study in general practitioners by Hall et al. (2018) also found evidence that the relationship between patient safety and burnout was a cycle, such that patient safety issues lead to burnout, and burnout leads to patient safety issues[50]

In addition, the current systematic review includes only one study of patient satisfaction, which found no evidence of a connection between surgeon burnout and patient satisfaction. That result is contrary to the one obtained by Anagnostopoulos et al., which showed that physician burnout affected patient satisfaction [51]. Nevertheless, due to the mixed findings, there is a need for further for studies to clarify the link between surgeon burnout and surgical professionalism as well as patient satisfaction. Perhaps, the research designs will have to be broadened to include a focus on underlying factors that cause the difference in results. A possible alternative explanation for the disparate results could be that cultural differences or commonly accepted behaviours cause some surgeons to go on sick leave earlier than other surgeons. Surgeons may leave the work environment before they become burnt out and return when they have had a period of recovery.

The meta-analysis found the association between burnout and medical errors was similar in US and non-US countries, suggesting this association may be a global phenomenon.

Implications for practice and future research

These results suggest that reducing surgeon burnout may improve the quality of patient care and surgical professionalism. Similarly, improving the quality of care surgeons are able to provide may help to reduce surgeon burnout as the association between burnout and medical errors appears to be cyclical. Therefore, there is an urgent need for the development of effective and evidence-based interventions to improve 1) burnout and 2) patient safety, which will likely also feed back into helping to reduce surgeon burnout.

While a systematic review synthesising studies across physicians suggested that interventions such as the one aimed at improving the culture of health care organizations and interventions focused on individual physicians may reduce burnout in physicians broadly [5], there is currently insufficient evidence for a synthesis of studies in surgeons in particular. Given the time pressure healthcare systems are under in the wake of the COVID-19 pandemic [52], having access to evidence-based and time-limited interventions is crucial in ensuring optimal use of staff time and resources.

Surgeon burnout is costly to healthcare organizations and jeopardizes a core social demand for safe care. On the other hand, medical errors have a substantial financial cost. Whereas surgeons are less likely than other medical practitioners to seek assistance[53], to solve these issues, organizations, surgeons, and psychologists should work together to deliver more effective interventions for surgeons, which may enhance surgeon retention.

Furthermore, more research is needed which focuses on the impact of surgeon burnout on patient care across a wider range of countries, to help establish whether there are cultural differences in how burnout affects surgeons and surgical practice. Also, there is a need for studies into surgeon burnout reduction interventions in low and middle-income countries in particular. To date, the great majority of studies have been in high-income countries [54-56], but these may not translate to other nations. Finally, a recent review has shown that surgical trainees are more burned out than their non-surgical counterparts[48], therefore, healthcare providers ought to also explore how training programmes can be modified to help support trainees earlier in their careers.

Strengths and limitations

This review has a number of strengths, including a large sample size of surgeons in the included studies (n = 27,248) and the use of meta-analysis which enabled the strength of the association between burnout and patient safety incidents to be estimated. The review included nine studies for meta-analysis, which is above the median number of studies included in a Cochrane review which is six [57]. However, it should be noted that this number falls below 10, which may have reduced the ability of the Egger test to detect publication bias. According to Sterne et al., if there are fewer than 10 studies in a meta-analysis, funnel plot asymmetry cannot be used as reliably because test power is normally insufficient to differentiate chance from true asymmetry [58]. Other limitations of the review pertain directly to the limitations of the studies used. More specifically, five of the included studies use only one question to measure patient safety [7,24,27-29]. There was heterogeneity across the studies due to having only nine studies in the meta-analysis and the poor quality per our evaluation in the measurement of patient safety, which is also likely to be to the detriment of the findings. This is an indication of the need for more and higher quality prospective studies to be carried out which can examine this association longitudinally.

There were also some limitations in relation to the representativeness [20,25,30,59], randomisation [26,27,30,31], and blinding [34,59] of original studies, with these studies scoring as low or unclear on these variables. However, low scores on such variables are common in previous similar reviews [10].

Conclusion

This systematic review and meta-analysis found surgeon burnout was significantly associated with higher incidence of medical errors. This shows that there is a pressing need for more interventions to help surgeons improve their wellbeing, as this may help reduce burnout occurrences, result in a reduction of medical errors and improved client satisfaction in healthcare settings. The findings of this research can therefore be used as a stimulus to put in place better policies and support, in order to reduce or prevent surgeon burnout. Conducting more in-depth future research can help understand the associations between surgeon burnout and environmental factors. Gaining a better understanding of environmental factors that cause burnout can lead to better decision-making among the people in charge of healthcare administration.

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Authors' contributions:

T.G., J.J., CSB and DOC were responsible for designing and implementing the research, analysing the results, and writing the manuscript.

A.D. Helped with 10% of abstract screening and full-text screening and K.H. helped with 10% of data extraction and quality assessment.

Data availability statement

All data are available from the first author on request

Conflict of interest: None of the authors have a conflict of interest to declare.

Ethical approval: An ethical committee's permission or patient consent were not required for this study.

Table 1: Characteristics of the studies included in the review:

1st Author	Year	Country	Design	Sample of Surgeons	Speciality	Gender	Burnout Measure	Patient Safety	Professionalism	Key Finding	Significant correlation
Balch[24]	2011	America	Cross-sectional survey	7,164	Breast:285 Cardiothoracic:436 Colorectal: 264 General: 2,737 Neurology: 164 Obstetrics and gynecology:83 Oncologic: 227 Ophthalmologic:152 Orthopaedic:149 Otolaryngology: 409 Paediatric: 224 Plastic:370 Transplant:124 Trauma:324 Urologic:306 Vascular:460 Other:440 Missing: 40	Male: 6,116 Female: 1,049 Missing: 32	The Maslach Burnout Inventory (MBI)		Malpractice lawsuits "Have you gone through a medical malpractice suit in the last 2 years?"	Recent malpractice suits were strongly related to burnout ($p < 0.0001$).	Significant
Crijns[25]	2020	America	Cross-sectional survey	203	Hand surgery: 84 Orthopaedic trauma: 66 Shoulder and elbow:17 Arthroplasty: 7 General surgery:7 Foot and ankle 6 Surgical sports 5 Paediatric 4 Plastic surgery 4	Male: 186 Female:17	MBI	Medical error "How many days in the last 3 months have you been uncomfortable in the aftermath of care or worried about errors or adverse		A greater level of emotional exhaustion was associated with a greater number of perceived medical errors	Significant

								events in spite of conscientious effort?"			
Coombs[26]	2020	America	Cross-sectional survey	146	plastic surgeon: 146	Male:84 Female:61	Stanford Professional Fulfillment Index	Stanford Professional Fulfillment Index(Include admission of medical errors)		Burnout was significantly associated with reporting making a major medical error that could have harmed a patient.	Significant
Faivre[27]	2018	France	Prospective survey	107	Orthopaedic and trauma surgery	Male:70 Female:37 Missing:	MBI	Medical error (single question)		The statistical analysis identified 3 risk factors for burnout syndrome, one of them being medical errors (odds ratio [OR], 8.8; 95% confidence interval [95% CI], 1.7–58.7; p = 0.0121).	Significant
Hewitt[32]	2020	America (Chicago)	Cross-sectional survey	7395	General surgeons	Male: 4530 Female: 2831	MBI	Self-reported error (Have you had medical error in the last 6 months?, follow-up a single question regarding near-miss medical errors and a single question		Residents were more likely to report a harmful medical error if they reported frequent burnout symptoms [OR 2.71 (95% CI 2.16–3.41)] or poor psychiatric well-being [OR 2.36 (95%), CI 1.92–2.90)].	Significant

								about patient harm)			
Kassam[28]	2020	U.S.	Cross-sectional survey	77	Transplant surgery:77	Male:50 Female:27	MBI	Medical error (single question)		surgeons with burnout were more likely to make a medical error (35.3% vs 5.2%, p=0.003).	Significant
Klein[33]	2010	German	Cross-sectional survey	1311	General surgery:681 gynaecological : 241	Male:789 Female:522	The Copenhagen Burnout Inventory (CBI)	Medical error (2 questions; diagnostic errors and therapeutic errors)	Self-rated patient care (Chirurgisches Qualitassiegle)	Burnout is significantly associated with perceived quality of care among male (OR from 1.5 to 2.6) but not among female surgeons (OR from 1.3 to 1.5).	Significant about male
Qureshi[7]	2015	America	Pilot survey	1691	plastic surgeons 169	Male:1243 Female:425 Missing:23	MBI	Medical error (single question)		plastic surgeons with burnout also had a nearly two-fold increased risk of self-reported medical errors and self reported impairment	Significant
Shanafelt[29]	2010	America	Cross-sectional survey	7,905	Missing: 44 Cardiothoracic: 489 Colorectal 302 Dermatologic 2 General 3233 Otolaryngology 368 Obstetrics/gynecology 105 Oncologic 407 Pediatric181 Plastic 458 Transplant 123 Trauma 345	Male:6815 Female:1043 Missing:	MBI	Medical error (a single question about have you made a major medical error in last three months, follow up with another question	-	Reporting an error during the last 3 months had a large, statistically significant adverse relationship with all 3 domains of burnout (emotional exhaustion, depersonalisation and personal accomplishment).	Significant

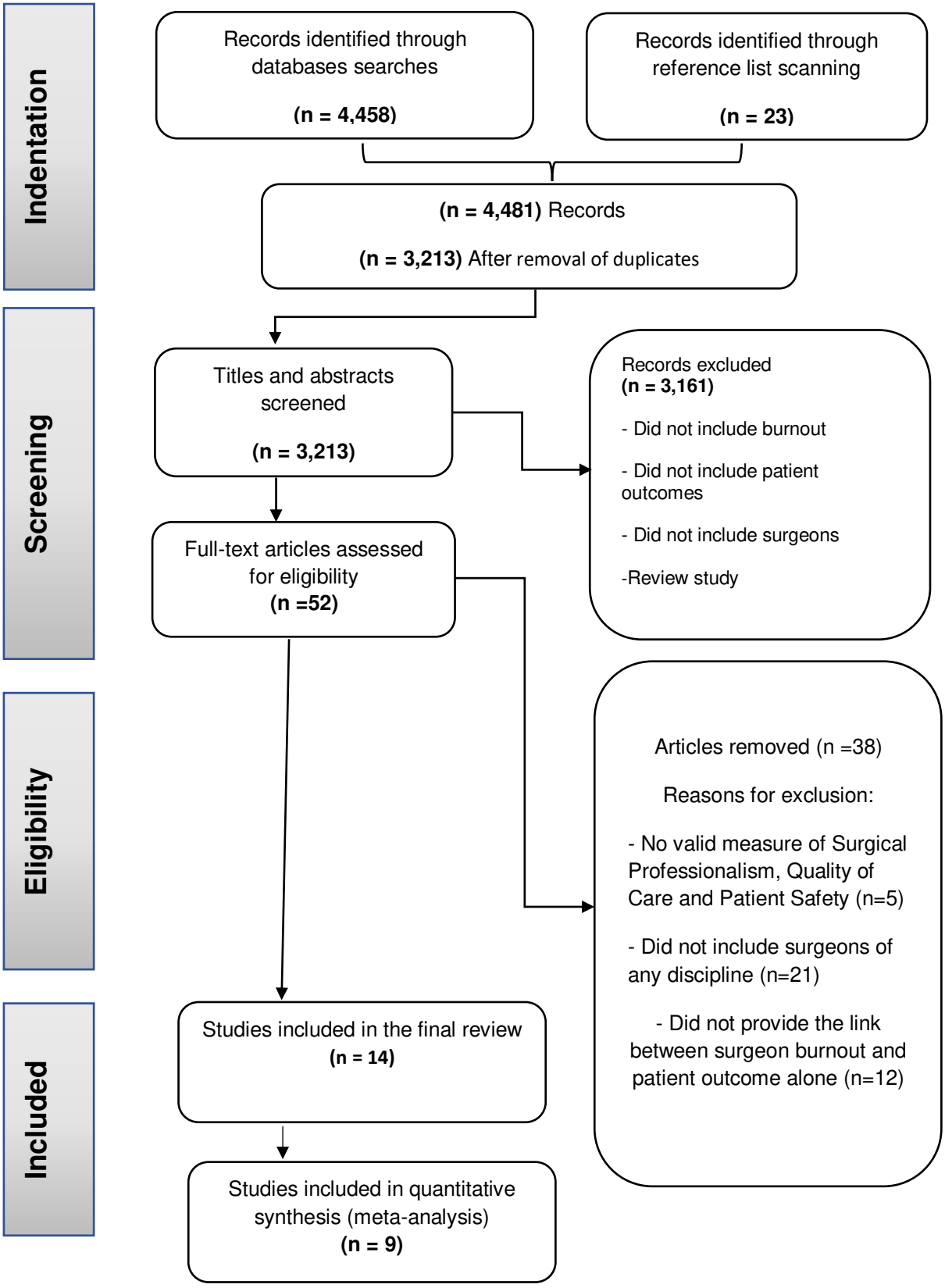
					Urologic 315 Vascular 463 Other 488			related to Greatest contributing factor in medical error)			
Soh[30]	2020	America	Cross-sectional survey	871	Unclear	Unclear	MBI		Reported malpractice allegations in the preceding 2 years	Malpractice allegations were significantly associated with surgeon burnout (odds ratio, 1.78 [1.01-2.15]; P.041)	Significant
Tsiga[35]	2017	Greece	Cross-sectional survey	117	Unclear	Unclear	MBI	Medical error checklists (MEC)		Regarding the frequency of medical errors, the results show significant positive associations with emotional exhaustion (R = 0.200, p = 0.006) and depersonalisation (R = 0.264, p = 0.005).	Significant
Walocha[20]	2013	Poland	Cross-sectional survey	19	Unclear	Unclear	MBI		Empathy Mehrabian and Epstein Emotional Empathy Scale (EES)	For the whole group, negative correlations were noted between the level of emotional exhaustion, depersonalisation and the total level of burnout (according to MBI) and the level of empathy (according to TAT) (r = –0.30, p <0.05; r = –0.39, p <0.01;	Negative correlation

										p = –0.32, p <0.01, respectively).	
Windover[34]	2018	America	Cross-sectional cohort design	139	Unclear	Unclear	MBI		Patient satisfaction "Consumer Assessment of Healthcare Providers and Systems surveys"	There was no significant association between burnout and productivity or patient satisfaction with inpatient or specialty care.	Not significant
Zheng[31]	2018	China	Cross-sectional survey	202	Orthopaedic .surgeons:202	Male:202 Female:0	MBI		Losing temper The last section of the questionnaire was designed to investigate intraoperative irritability, including frequency, possible reasons, consequences, participants' attitude and career satisfaction.	The overall rate of burnout was 85.1%. Variables were significantly associated with high emotional exhaustion.	Significant

Table 2: Speciality of surgeons in included studies (N =27,248 participants)

Number of studies	Speciality	Number of surgeons	Percentage of speciality (out of total number of surgeons)
Four studies [24,25,29,33]	General surgery	14,572	53.48%
Four studies [7,24,26,29]	Plastic surgery	2,669	9.80%
Five studies [24,25,27,29,31]	Orthopaedic and trauma surgery	1,310	4.81%
Two studies [24,29]	Cardiothoracic surgery	925	3.39%
Two studies [24,29]	Vascular surgery	923	3.41%
Two studies [24,29]	Oncologic surgery	919	3.37%
Two studies [24,29]	Otolaryngology surgery	777	2.85%
Two studies [24,29]	Urology surgery	621	2.28%
Two studies [24,29],	Colorectal surgery	566	2.08%
One study [24]	Ophthalmologic surgery	152	0.56%
Two studies [24,29]	Paediatric surgery	405	1.49%
Three studies [24,29,33]	Obstetrics and gynaecology surgery	429	1.57%
Three studies [24,28,29]	transplant surgery	324	1.19%
One study [24].	Neurosurgery	164	0.60%
One study [29]	Dermatologic surgery	2	0.01%
Five studies [20,24,29,34,35].	No clear speciality (surgeons not mention their speciality)	1.869	6.86%

Figure 1: Flow diagram of article selection



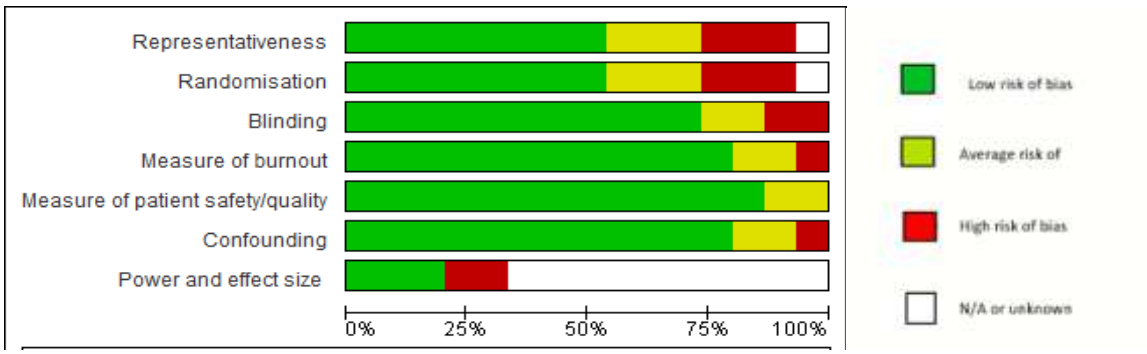


Figure 2: The overall study quality and risk of bias profile across 14 studies

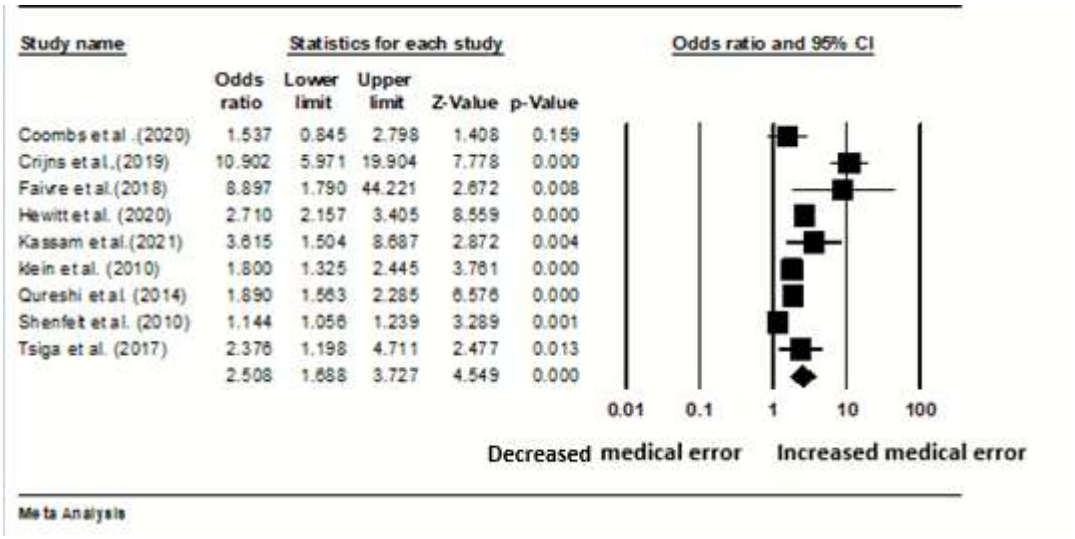


Figure 3: A proportional forest plot of the relationship between surgeon burnout and medical error (k = 9)

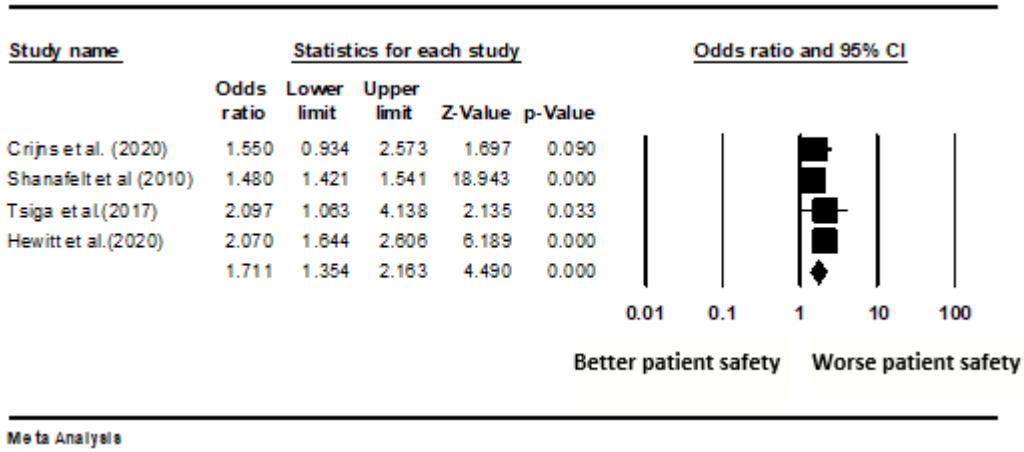


Figure 4-a: A proportional forest plot of the relationship between surgeon emotional exhaustion and patient safety outcome (k = 4)

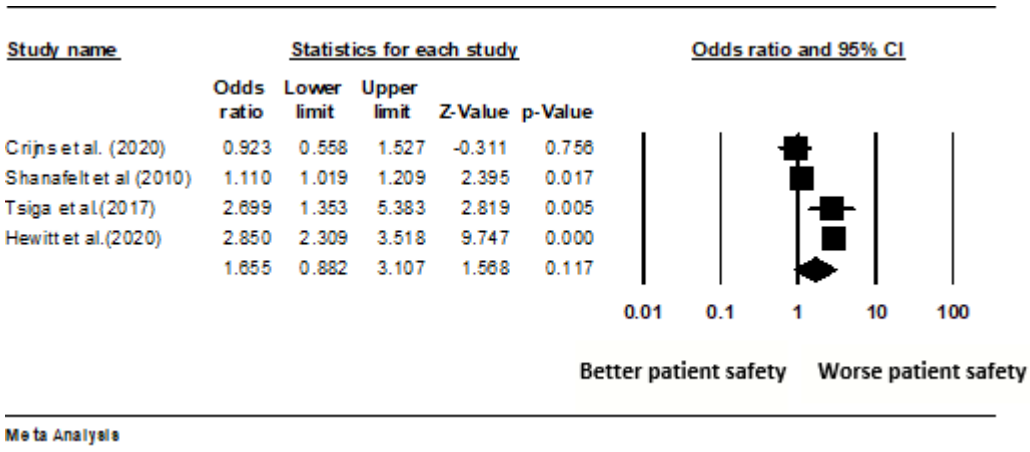


Figure 4-b: A proportional forest plot of the relationship between surgeon depersonalisation and patient safety outcome (k = 4)

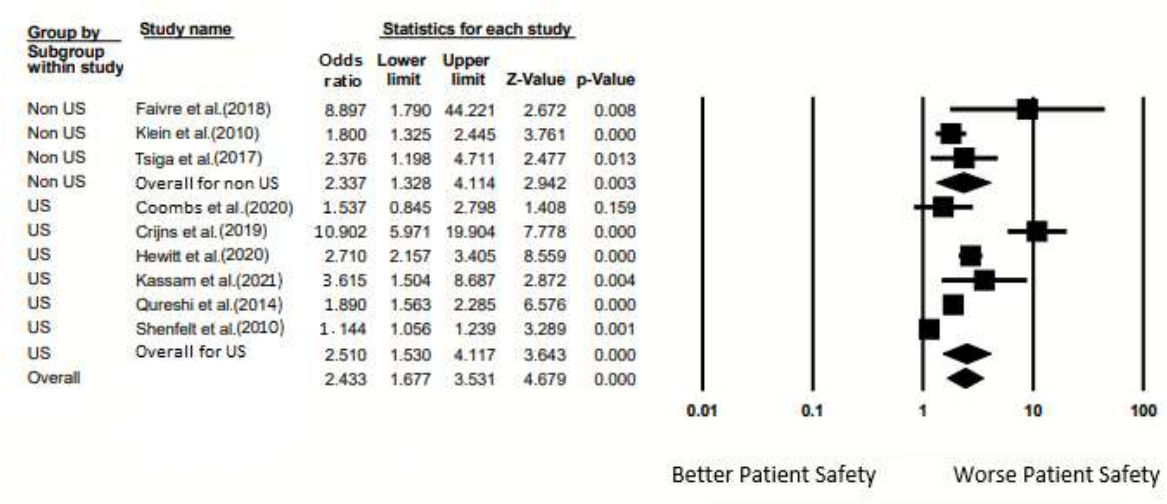


Figure 5: A sub-group analysis between US and non US studies.

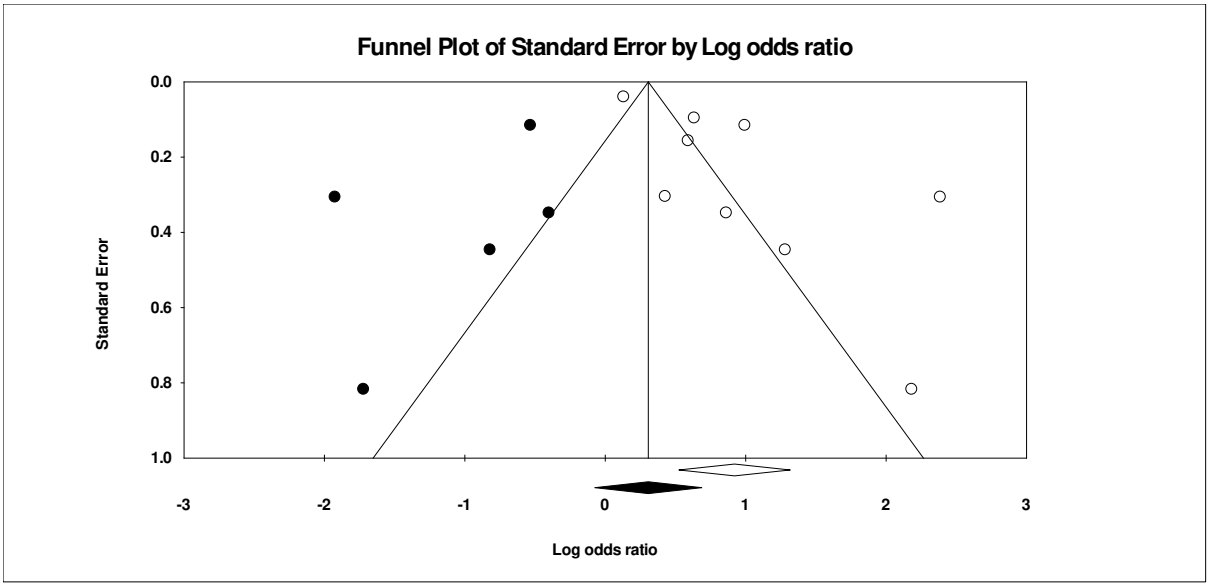


Figure 6 Funnel plot of publication bias with observed (white) and imputed (shaded) studies

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