

1 SURGEONS' PERCEPTIONS OF THE CAUSES OF PREVENTABLE HARM
2 IN ARTERIAL SURGERY AND STRATEGIES
3 TO IMPROVE PATIENT SAFETY:
4 A MIXED METHODS STUDY
5

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25 WHAT THIS PAPER ADDS

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27 It is well established that patient risk factors and variation in procedural volume or
28 technique are related to patient outcome. What this study adds is a summary of
29 vascular surgeons' reports of broader 'system' factors influencing the safety of
30 patients undergoing arterial surgery. Vascular surgeons perceive that adverse events
31 are not solely related to inherent complexities in the procedure or the patient's
32 condition, but are commonly caused by a combination of team, environment and
33 organisational failures, which may combine to cause harm.

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49 **ABSTRACT**

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51 **Background:** System factors contributing to preventable harm in vascular patients
52 undergoing surgery have not been previously reported in detail. The aims of this
53 mixed methods study were to describe vascular surgeons' perceptions of factors
54 contributing to adverse events in arterial surgery and to propose strategies to improve
55 patient safety.

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57 **Methods:** Vascular consultants and registrars working in the National Health Service
58 (NHS) in the United Kingdom (UK), were questioned about their perceptions of the
59 causes of preventable adverse events in arterial surgery through survey and semi-
60 structured interview (response rates 77% and 83%, respectively). Survey respondents
61 considered a recent adverse event they had personally witnessed in arterial surgery
62 and indicated on a 5-point Likert scale the extent to which various factors from a
63 validated framework contributed toward the incident. Ten semi-structured interviews
64 were conducted to obtain more detailed accounts of observed contributory factors,
65 and to elicit vascular surgeons' recommendations to improve outcomes.

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67 **Results:** Seventy-seven vascular surgeons completed the survey describing 77
68 separate adverse events, which occurred during open arterial surgery (n=41), and in
69 endovascular arterial procedures (n=36). 83% of surgeons reported multi-factorial
70 causes (median number of contributory factors per adverse event = 5, IQR 3-9, range
71 0-25). Most frequently reported contributory factors related to three themes: team
72 factors (communications failures, lack of clarity over role and responsibilities, lack of
73 team continuity), work environment factors (inadequate staffing levels or skill mix,
74 equipment problems, external pressures), and training/supervision. To improve

patient safety, vascular surgeons proposed team training programs to improve technical skills, crisis management, and communication and collaboration between the disciplines.

Conclusion: Vascular surgeons report that adverse events are caused by multiple, modifiable factors. While technical skills and patient factors remain important determinants of outcome, vascular surgeons would like to see the implementation of wider safety improvement strategies to reduce avoidable patient harm.

Key words: patient safety; adverse events; arterial surgery

99 INTRODUCTION

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101 Some of the highest rates of preventable adverse events are in vascular patients
102 undergoing surgical intervention (1–5), yet few studies have sought to identify the
103 preventable causes of these incidents in vascular surgery. Operator and institution
104 inexperience, deficiencies in technical skills and inappropriate patient selection are
105 known to be associated with poorer outcomes (6). In a small number of single-centre
106 studies, observers have reported failures relating to equipment, workspace
107 configuration, communication, and teamwork (7,8). These findings have been
108 corroborated in a larger, multi-centre observational study of ‘system’ failures in aortic
109 surgery in the UK (9). Non-technical failures have been linked to intra-operative
110 errors, procedural problems and longer operating times, but their *direct* relationship
111 with patient harm is less clear. To ensure the best outcomes, the vascular community
112 must seek to understand the preventable causes of adverse events and target
113 interventions to improve safety across the specialty. Vascular surgeons are ideally
114 placed to comment on factors leading to adverse events, yet to date their views have
115 not been formally reported. The aim of this mixed methods study was to describe
116 vascular surgeons’ perceptions of factors contributing towards adverse events in
117 arterial surgery. A secondary aim was to report vascular surgeons’ recommendations
118 for improving the safety of these patients.

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METHODS

Overview and definitions

In this mixed-methods study, surveys and semi-structured interviews elicited vascular surgeons' perceptions of the causes of adverse events in patients undergoing arterial surgery, and interviewees were asked to provide recommendations for improving the safety of these patients. 'Adverse events' were defined as unintended injuries to patients caused by medical management rather than the patient's underlying condition, leading to prolonged hospital stay, temporary or permanent disability, or death (10).

Inclusion criteria and recruitment of participants

To obtain a high response rate, 100 surgeons were randomly approached face-to-face during three vascular conferences between November 2012 and September 2013 and were invited to complete the survey. Potential interviewees were identified through clinical contacts and contacted via email with an invitation to participate. Surgeons were eligible to complete the survey or participate in an interview if they regularly performed arterial operations (both open and endovascular procedures) in the British NHS as vascular consultants, as vascular registrars, or as general surgery registrars with a sub-interest in vascular surgery. Interviews continued until a diverse sample in terms of level of training, gender and work location was obtained. Apart from verbal confirmation from survey respondents that they worked in the British NHS, specific work location was not recorded because of concern that this would deter potential respondents for anonymity reasons and thus reduce the sample size.

Materials and methods

A validated framework of factors known to contribute to adverse events in healthcare was used to devise the survey. The framework, which is described in full elsewhere (11,12), lists 25 contributory factors organised under the following headings: patient, staff, teams, the work environment, organisation and management, and institutional context. Respondents were asked to consider each contributory factor in relation to an adverse event: (1) that they had personally witnessed and could recall the circumstances of, (2) that had occurred during or within 24 hours of an open or endovascular arterial procedure, and (3) that was caused by medical management rather than underlying disease, and resulted in prolonged hospital stay, disability or death. A Likert scale was used for the survey because Likert scales are commonly used to measure attitudes or beliefs, are familiar to healthcare professionals and facilitate ease of survey completion by providing the respondent with a range of responses (13). Respondents scored all factors in relation to the adverse event; a score of 5 was 'highly likely' to have contributed, a score of 1 was 'highly unlikely' to have contributed and a score of 3 was neutral. However, to facilitate comparison between groups (consultants versus registrars; emergency versus elective procedures) in a small sample, survey responses were later converted to binary variables, where factors judged as at least 'somewhat likely' to have contributed to adverse events were coded as 1, and the remainder were coded as 0. Respondents were also asked to indicate their level of training (consultant or registrar), the type of procedure that the adverse event related to (open or endovascular surgery), whether the procedure was elective or emergency, and the consequences of the adverse event. To preserve anonymity and to encourage a higher response rate, survey respondents were not asked to give their name or work location. The survey was piloted with eight vascular trainees to ensure

acceptability with subsequent minor changes the syntax of instructions. Survey administration was paper-based, and was undertaken by a single researcher (RL: clinical research fellow). The semi-structured interview schedule elicited detailed accounts of perceived factors leading to adverse events, as well as recommendations to improve patient safety in arterial surgery. All interviews were undertaken by a single researcher, recorded, transcribed verbatim by a professional independent transcriber, anonymised and assigned a study identification number

Analysis

Survey responses were treated as binary variables (factor contributed or did not contribute to adverse event), as were level of training (consultant versus trainee) and surgery type (open versus endovascular). The most frequently reported contributory factors were calculated. It was hypothesised that the following characteristics could influence perceptions of the profile of factors contributing towards an adverse event: (1) respondent's level of training (consultant versus trainee), (2) procedure type (open versus endovascular) and (3) setting (elective versus emergency). These hypotheses were tested using Pearson's chi-square analysis with application of the Bonferroni correction to adjust to for multiple comparisons.

Analysis of interview transcripts adhered to the principles of the 'framework method', which outlines key steps in the process of thematic analysis (14) to ensure a systematic approach (box 1). The researcher (RL), who had received formal training in the framework method, read all transcripts in detail, searching for common themes. Themes that were specified a priori (common contributory factors identified through analysis of survey data) and new themes emerging from the data were combined to

form an analytical framework, comprised of a number of themed headings. This thematic framework was applied to all transcripts. Coded transcript data and relevant illustrative quotes were arranged in a theme/case matrix in Microsoft Excel.

Box 1: Steps in qualitative data management using the Framework approach (14)

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Step 1: familiarisation with transcripts to identify data relevant to the research question

Step 2: construction of a thematic framework from the data itself through identification of headings under which relevant data can be organised

Step 3: indexing and sorting to identify parts of the data that can be grouped together

Step 5: reviewing data extracts to organise data to create more coherent groupings

Step 6: data summary and display to summarise each interviewee's contribution to a theme

Step 7: abstraction and interpretation to map the range and diversity of views and experiences, and to suggest explanations for the findings.

RESULTS

Of 100 vascular surgeons approached, 77 completed the survey (response rate 77%) and reported on 77 separate adverse events. Survey respondents were consultants (n=37) and registrars (n=40), working in the British National Health Service who regularly perform open and endovascular arterial procedures. Twelve vascular surgeons were invited to be interviewed, and ten agreed to participate (response rate 83%). Interviewees were consultants (n=5) and registrars (n=5) from six different hospitals across England. All interviewees regularly performed open and endovascular procedures in arterial ‘hubs’ (centres where arterial expertise are concentrated following the process of centralisation in the UK). Four interviewees worked in central London hospitals and seven worked in other regions. Table 1 presents an overview of the procedures types, settings and consequences of the adverse events reported by the survey respondents and interviewees. For illustrative purposes, the details of three adverse events reported by interviewees, including the sequence of events and perceived contributory factors, are presented in table 2.

- Tables 1 & 2 –

Overview of contributory factors

Eighty-three percent of survey respondents reported that multiple factors contributed to the adverse event they had witnessed (median number of factors = 5, interquartile range (IQR) 2-9, range 0-25). Table 3 outlines the profile of contributory factors reported by 77 survey respondents for 77 separate adverse events. Aside from the patient’s condition, the most frequently reported contributory factors were failures in

verbal communication between operating team members (36.4%; n=28/77), inadequate staffing levels or skill mix (32.5%; n=25/77), and a lack of knowledge, skills (37.3%; n=28/75) or competence (32.9% (25/76). There were no significant differences between consultants and registrars for the pattern of contributory factors reported. Although the pattern of contributory factors did not differ significantly between elective or emergency procedures, data for the urgency of the procedure was missing in 32.5% (25/77) of survey responses and therefore these results are not presented in further detail. Failures relating to knowledge or skill were more frequently cited as contributing to adverse events (AEs) in open procedures compared with endovascular procedures (19 AEs versus 9 AEs, $p = 0.034$), as were failures relating to competence (18 AEs versus 7 AEs, $p = 0.018$). Issues relating to organisational structure were more frequently reported as contributing to adverse events in endovascular procedures than in open procedures (10 AEs versus 3 AEs, $p = 0.017$).

- Table 3 -

Most frequently reported themes arising from survey responses and thematic analysis of interview transcripts are outlined in table 4 and are also described in depth below.

Verbatim quotes are given in italics.

- Table 4 -

Team Factors

More than one third of survey respondents (36.4%) and eight of ten interviewees indicated that verbal communication failures had contributed towards an adverse

event that they had witnessed. Intrinsic factors leading to poor communication were reported as a reluctance to challenge perceived authority *“I didn’t feel I could speak up being a more junior member of the team”* (interviewee 9, registrar), or a desire to demonstrates one’s own capabilities without senior help: *“Knowing when to ask for help, that element of communication is difficult. I think it goes back to the hierarchy, and almost proof of self-worth”* (interviewee 10, registrar). Long cases requiring staff changeover intra-operatively were viewed as particularly vulnerable to communication failure: *“...the only one who tends to be constant is the operating surgeon and if there is a complex case which takes many hours and requires shift changes, it is easy to see how things can be forgotten like an extra clamp that has been left on too long, a swab that has been placed under the pelvis”* (interviewee 10, registrar). Problems relating to team structure (congruence, consistency, leadership) were reported by 28.9% of survey respondents and by four of ten interviewees. Unfamiliarity with other team members made it more challenging to operate safely, and this was particularly problematic during emergency cases occurring out-of-hours: *“the scrub teams, the emergency scrub team, which is very incongruent, just sort of thrown together [...] I’d never met my assistant before, never mind worked with her”* (interviewee 7, consultant). Poorly defined roles and responsibilities within the operating team were described by three interviewees. In one case, it was not clear who was responsible for confirming delivery of an essential piece of kit – failure to check that the equipment had been received led to the planned operation being cancelled after the patient had been put under general anaesthesia (interviewee 3, consultant).

Work Environment Factors

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300 Nearly half of survey respondents (48.1%) reported that work environment factors
301 contributed to adverse events. Inappropriate staffing levels or skill mix were cited by
302 32.5% of all survey respondents and by seven out of ten interviewees. Two new
303 consultants felt that having to rely on inexperienced team members impeded their
304 ability to concentrate on operating, and six of ten interviewees cited distractions and
305 external pressures- such as concurrent emergencies- as factors contributing towards
306 adverse events. Other distractions in the work environment (light, space, noise) were
307 reported by 14.5% of survey respondents.

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309 27.3% of survey respondents and eight of ten interviewees reported issues relating to
310 the design, availability and use of equipment. Half of interviewees (5/10) described
311 failures in planning or preparing essential equipment: two interviewees felt that
312 adverse events had occurred because appropriate rescue equipment was not available
313 when required. Three interviewees reported that unfamiliarity with equipment
314 contributed towards adverse events they had witnessed.

315

316 *Lack of supervision/training*

317 28.7% of survey respondents and nine of ten interviewees indicated that failures in
318 supervision or failing to seek help were important determinants of adverse events:
319 *"the surgical consultant saw that I was struggling and I kept asking for advice on*
320 *what to do for surgical components but I never said I need you to scrub. Without that*
321 *direct demand and I guess in part my own inexperience the patient lost a reasonable*
322 *amount of blood"* (interviewee 10, registrar). Four interviewees described difficulty
323 in managing of the operating environment and the team due to a lack of training in

‘soft skills’: “...for the relatively inexperienced consultant’s level, it takes up a lot of, you know, thinking part of the brain, to have it concentrate on reminding the assistant as well as concentrating on what’s a very technically demanding procedure”

(interviewee 7, consultant).

Strategies to improve patient safety

Interviewees suggested a variety of strategies to improve patient safety in arterial surgery (table 6). Half of interviewees (5/10) would like to implement training programs enabling the entire multi-disciplinary operating team to train together. One interviewee emphasised that team training would be particularly important to rehearse crisis scenarios. Four interviewees suggested implementing further protocols or checklists to standardise processes such as mid-procedure handovers between staff. Two interviewees believed that high-risk procedures are safest when performed by experienced operating team members who have worked together for many years. Current issues with staff retention or rotation were acknowledged as barriers to this “old fashioned” way of working. It was argued that: “...if you can’t have a blanket policy where the safety is always number one, because, it’s impossible to have this level of expertise all the time – then you’ve got to make sure you have it there for cases where things start to become emergent” (interviewee 6, registrar).

Accordingly, three interviewees would like to implement further escalation algorithms to facilitate adequate staffing levels or skill mix during emergencies.

- Table 5 -

DISCUSSION

The purpose of this study was to describe vascular surgeons' perceptions of factors contributing to adverse events in arterial surgery. Vascular surgeons report that adverse events are not solely related to inherent complexities in the procedure or the patient's condition, but are commonly caused by a combination of team, environment and organisational failures.

We adopted a novel, mixed-methods approach for this study. We measured surgeons' survey responses against an existing framework, but we also searched for themes in interview transcripts and we provide direct quotations from interviews with surgeons in this report. Although this approach might seem alien in a field that relies heavily on quantitative experimental designs, there are several advantages to using a qualitative or mixed-methods methodology when seeking to understand why adverse events occur. Whereas quantitative research measures frequency, prevalence and incidence, qualitative research seeks to understand the breadth and complexity of a given topic (15). Hence qualitative methodologies are appropriate when investigating the complex interplay of factors contributing towards adverse events, particularly as potentially relevant factors are not fixed in time and space. An advantage of pairing quantitative and qualitative methods is increased confidence in study findings through triangulation (ref Quinn et al). Indeed, in the present study, the independent responses of survey respondents and interviewees both indicated that team and work environment factors are important determinants of adverse events. However, the interviews revealed a more nuanced interpretation of this relationship— for example, whereas analysis of survey results demonstrated that communication failures

frequently resulted in adverse events, analysis of interview transcripts revealed some of the factors underpinning these communication failures – such as lack of team continuity or confusion over roles and responsibilities within multidisciplinary teams.

Looking at the findings of this study it is possible to infer that many of the problems leading to patient harm in arterial surgery are common across all surgical specialties. Communication failure, for example, is a widely recognised determinant of patient harm, particular in the operating theatre (16). Vascular surgeons in this study reported that communication failures may be exacerbated by the issue of operating team continuity. This issue has also been reported in other surgical specialties involving long and complex operations – for example, in a large retrospective cohort study of patients undergoing cardiac surgery, the need to handover anaesthetic care from one anaesthetist to another was associated with a 27% relative increase in risk-adjusted, post-operative complications compared to cases in which the same anaesthetic team members were present throughout the operation (17). In a further study of outcomes in patients undergoing abdominal surgery, surgeons reported higher levels of concentration when they consistently worked with the same operating team members, and this study demonstrated that team familiarity was a significant predictor of post-operative complications (18). Work environment factors including staffing levels or skill mix and equipment issues have also been widely reported in the safety literature. Nurse staffing and education level is strongly associated with outcomes in surgical patients (19,20). Furthermore, cumulative operating team experience has been shown to be more important than the individual experience of the most senior surgeon in cardiac operations with regards to cardiopulmonary bypass and clamp times (21). This is concerning because vascular surgeons in the present

study pointed out that they frequently work with very junior assistants or scrub nurses with little experience of major arterial procedures. Vascular surgeons also reported that equipment issues are common contributory factors when adverse events occur. These reports echo the findings of several other studies of safety in surgery, which have demonstrated that equipment failures are common during arterial operations, occurring most frequently during procedures that utilise endovascular technology (7–9,22). A systematic review of equipment failures in the operating theatre demonstrated that procedures relying more heavily on technology, such as those in vascular and cardiac specialties, carried a higher burden of equipment-related error than general surgical procedures (23). In the context of the wider surgical literature, the issues identified in the present study are unlikely to come as a surprise to most vascular surgeons, but publishing this work within the vascular surgical literature is an important move towards increasing the visibility of these problems for policy makers.

This study raises some concerns that are unique in the field of vascular surgery, particularly in relation to the organisation of endovascular services in the UK and some other European countries. Organisational structure was associated with a higher incidence of adverse events in endovascular procedures than open procedures, and vascular surgeons described errors in communication as a result of the involvement of two teams (surgical and interventional radiology) in one procedure, as is common practice in the UK. This finding has been echoed in a larger, multi-centre study of intraoperative failures in aortic procedures in the UK, in which procedure type independently predicted intraoperative failure rate - with endovascular procedures associated with significantly higher rates of intraoperative equipment-related and

communication failures (9). Further research could compare adverse events in patients undergoing endovascular procedures at centres where there is complete integration of vascular and interventional radiology teams versus centres where there is demarcation of territory. It is likely that, to improve patient safety in the UK, we need to standardise the provision of training in endovascular skills to theatre nurses alongside greater integration of vascular and interventional radiology teams as is commonplace in many European countries. Interviewees in the present study emphasized the need for multidisciplinary teams to train together as teams, rather than within separate disciplines. The feasibility of simulation-based team training to enable vascular operating teams to acquire both the technical and non-technical skills required for endovascular procedures has been demonstrated in some preliminary studies (24,25), but there is more work to be done in this arena.

Investigating the causes of adverse events in healthcare is challenging due to the broad range of potentially relevant contributing factors. There are a number of approaches that can be taken to address the problem and this study used a mixed-methods approach to capitalise on the strengths of both quantitative and qualitative methodologies as previously discussed. However, this study has a number of important limitations that must be acknowledged. Firstly, this study relied on accurate reporting of events by surgeons and is therefore vulnerable to the limitations of recall bias and selective reporting. Furthermore, as study participation was voluntary, surgeons with a particular interest in patient safety may have been more likely to participate, potentially introducing sample bias. This study is also limited in terms of generalisability as it only reflects practices within the British NHS and the relative importance of different contributory factors could not be established for

different types of institution (e.g. teaching centres versus district general hospitals) or for different procedures types (elective versus emergency procedures). Finally, it is important to note that reports of strategies to improve patient safety were based on interviewees with only ten vascular surgeons and more research is needed to determine the most effective strategies to reduce the incidence of patient harm.

CONCLUSION

Vascular surgeons believe that adverse events in arterial operations are frequently caused by multiple, modifiable system factors. Important themes include communication failure, lack of operating team continuity, inadequate staffing levels, equipment issues, distractions and external pressures, and inadequate training or supervision. More research is needed to establish the relative significance of these contributory factors in arterial surgery and to determine strategies that can effectively address system failures to prevent future adverse events and further improve surgical outcomes.

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501

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References **update reference list for final draft******

1. Gawande AA, Thomas EJ, Zinner MJ, Brennan TA. The incidence and nature of surgical adverse events in Colorado and Utah in 1992. *Surgery*. 1999;126(1):66–75.
2. Brennan TA, Leape LL, Laird NM, Hebert L, Localio AR, Lawthers AG, et al. Incidence of Adverse Events and Negligence in Hospitalized Patients: Results of the Harvard Medical Practice Study I. *N Engl J Med*. 1991;324(6):370–6.
3. Zegers M, de Bruijne MC, de Keizer B, Merten H, Groenewegen PP, van der Wal G, et al. The incidence, root-causes, and outcomes of adverse events in surgical units: implication for potential prevention strategies. *Patient Saf Surg* [Internet]. BioMed Central Ltd; 2011;5(1):13. Available from: <http://www.pssjournal.com/content/5/1/13>
4. Healey M a, Shackford SR, Osler TM, Rogers FB, Burns E. Complications in surgical patients. *Arch Surg* [Internet]. 2002 May;137(5):611–7. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/11982478>
5. Wilson RM, Runciman WB, Gibberd RW, Harrison BT, Newby L, Hamilton JD. The Quality in Australian Health Care Study. *Med J Aust*. 1995;163:458–71.
6. Karthikesalingam A, Hinchliffe RJ, Loftus IM, Thompson MM, Holt PJ. Volume-outcome Relationships in Vascular Surgery: The Current Status. *J Endovasc Ther* [Internet]. 2010 Jun;17(3):356–65. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/20557176>
7. Albayati MA, Gohel MS, Patel SR, Riga C V, Cheshire NJW, Bicknell CD. Identification of patient safety improvement targets in successful vascular and

548 endovascular procedures: analysis of 251 hours of complex arterial surgery.
549 Eur J Vasc Endovasc Surg [Internet]. Elsevier Ltd; 2011 Jun [cited 2013 Jan
550 13];41(6):795–802. Available from:
551 <http://www.ncbi.nlm.nih.gov/pubmed/21320788>

552 8. Patel SR, Gohel MS, Hamady M, Albayati M a., Riga C V., Cheshire NJW, et
553 al. Reducing Errors in Combined Open/Endovascular Arterial Procedures:
554 Influence of a Structured Mental Rehearsal Before the Endovascular Phase. J
555 Endovasc Ther. 2012;19:383–9.

556 9. Lear R, Riga C, Godfrey AD, Falaschetti E, Cheshire NJ, Van Herzeele I, et al.
557 Multicentre observational study of surgical system failures in aortic procedures
558 and their effect on patient outcomes. Br J Surg [Internet]. 2016; Available
559 from: <http://www.ncbi.nlm.nih.gov/pubmed/27557606>

560 10. Vincent C. Patient Safety. 2nd Ed. Chichester: Wiley-Blackwell; 2010.

561 11. Vincent C, Taylor-Adams S, Stanhope N. Framework for analysing risk and
562 safety in clinical medicine. BMJ [Internet]. 1998;316:1154–7. Available from:
563 [papers2://publication/uuid/2C21412B-ABD2-4344-914C-E0F1D42912F5](https://pubmed.ncbi.nlm.nih.gov/27557606)

564 12. Vincent C, Moorthy K, Sarker SK, Chang A, Darzi AW. Systems Approaches
565 to Surgical Quality and Safety. Ann Surg [Internet]. 2004 Apr [cited 2013 Mar
566 7];239(4):475–82. Available from:
567 [http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=](http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00000658-200404000-00007)
568 [00000658-200404000-00007](http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00000658-200404000-00007)

569 13. Jamieson S. Likert scales: how to (ab)use them. Med Educ [Internet]. 2004 Dec
570 [cited 2014 Mar 22];38(12):1217–8. Available from:
571 <http://www.ncbi.nlm.nih.gov/pubmed/15566531>

572 14. Ritchie J, Lewis J, Nicholls CM, Ormston R, editors. Qualitative Research

- Practice. 2nd Editio. London: Sage; 2014.
15. Curry L a, Nembhard IM, Bradley EH. Qualitative and mixed methods provide unique contributions to outcomes research. *Circulation* [Internet]. 2009 Mar 17 [cited 2013 Sep 20];119(10):1442–52. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/19289649>
 16. Nagpal K, Vats A, Lamb B, Ashrafian H, Sevdalis N, Vincent C, et al. Information transfer and communication in surgery: a systematic review. *Ann Surg* [Internet]. 2010 Aug [cited 2013 Feb 1];252(2):225–39. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/20647929>
 17. Hudson CCC, McDonald B, Hudson JKC, Tran D, Boodhwani M. Impact of anesthetic handover on mortality and morbidity in cardiac surgery: A cohort study. *J Cardiothorac Vasc Anesth* [Internet]. Elsevier; 2015;29(1):11–6. Available from: <http://dx.doi.org/10.1053/j.jvca.2014.05.018>
 18. Kurmann a, Keller S, Tschan-Semmer F, Seelandt J, Semmer NK, Candinas D, et al. Impact of team familiarity in the operating room on surgical complications. *World J Surg* [Internet]. 2014;38(12):3047–52. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/24989030>
 19. Aiken LH. Hospital Nurse Staffing and Patient Mortality, Nurse Burnout, and Job Dissatisfaction. *JAMA J Am Med Assoc* [Internet]. 2002;288(16):1987–93. Available from: <http://jama.jamanetwork.com/article.aspx?doi=10.1001/jama.288.16.1987>
 20. Aiken LH, Sloane DM, Bruyneel L, Van Den Heede K, Griffiths P, Busse R, et al. Nurse staffing and education and hospital mortality in nine European countries: A retrospective observational study. *Lancet*. 2014;383(9931):1824–30.

- 598 21. Elbardissi AW, Duclos A, Rawn JD, Orgill DP, Carty MJ. Cumulative team
599 experience matters more than individual surgeon experience in cardiac surgery.
600 J Thorac Cardiovasc Surg [Internet]. The American Association for Thoracic
601 Surgery; 2013;145(2):328–33. Available from:
602 <http://dx.doi.org/10.1016/j.jtcvs.2012.09.022>
- 603 22. Morbi AHM, Hamady MS, Riga C V, Kashef E, Pearch BJ, Vincent C, et al.
604 Reducing error and improving efficiency during vascular interventional
605 radiology: implementation of a preprocedural team rehearsal. Radiology
606 [Internet]. 2012 Aug;264(2):473–83. Available from:
607 <http://www.ncbi.nlm.nih.gov/pubmed/22668564>
- 608 23. Weerakkody RA, Cheshire NJ, Riga C, Lear R, Hamady MS, Moorthy K, et al.
609 Surgical technology and operating-room safety failures: a systematic review of
610 quantitative studies. BMJ Qual Saf [Internet]. 2013 Sep [cited 2013 Sep
611 28];22(9):710–8. Available from:
612 <http://www.ncbi.nlm.nih.gov/pubmed/23886892>
- 613 24. Rudarakanchana N, Van Herzeele I, Bicknell CD, Riga C V., Rolls A, Cheshire
614 NJW, et al. Endovascular repair of ruptured abdominal aortic aneurysm:
615 Technical and team training in an immersive virtual reality environment.
616 Cardiovasc Intervent Radiol. 2014;37:920–7.
- 617 25. Desender LM, Van Herzeele I, Lachat ML, Rancic Z, Duchateau J,
618 Rudarakanchana N, et al. Patient-specific Rehearsal Before EVAR. Ann Surg
619 [Internet]. 2016;XX(X):1. Available from:
620 [http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=](http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00000658-9000000000-96551)
621 [00000658-9000000000-96551](http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00000658-9000000000-96551)

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