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Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-006759
Article Type:	Research
Date Submitted by the Author:	17-Oct-2014
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Primary Subject Heading:	Surgery
Secondary Subject Heading:	Medical education and training
Keywords:	Feedback, Quality improvement, performance

THE IMPACT OF FEEDBACK OF INTRA-OPERATIVE TECHNICAL PERFORMANCE IN SURGERY: A SYSTEMATIC REVIEW

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Financial Disclosure and Products Statement

None of the participating authors has a conflicting financial interest related to the work detailed in this manuscript, nor do any of the authors maintain a financial stake in any product, device or drug cited in this report.

ABSTRACT

Objectives: Increasing patient demands, costs and emphasis on safety coupled with reductions in the length of time surgical trainees spend in the operating theatre necessitate means to improve the efficiency of surgical training. In this respect, feedback based on intra-operative surgical performance may be beneficial. Our aim was to systematically review the impact of intra-operative feedback based on surgical performance.

Setting: MEDLINE, Embase, PsycINFO, AMED and the Cochrane Database of Systematic Reviews were searched. Two reviewers independently reviewed citations using predetermined inclusion and exclusion criteria. 32 data-points per study were extracted.

Participants: The search strategy yielded 1,531 citations. Three studies were eligible, which comprised a total of 280 procedures by 62 surgeons

Results: Overall, feedback based on intra-operative surgical performance was found to be a powerful method for improving performance. In cholecystectomy, feedback led to a reduction in procedure time (p=0.022) and an improvement in economy of movement (p<0.001). In simulated laparoscopic colectomy, feedback led to improvements in instrument path length (p=0.001) and instrument smoothness (p=0.045). Feedback also reduced error scores in cholecystectomy (p=0.003), simulated laparoscopic colectomy (p<0.001) and simulated renal artery angioplasty (p=0.004). In addition, feedback improved balloon placement accuracy (p=0.041) and resulted in

a smoother learning curve and earlier plateau in performance in simulated renal artery angioplasty.

Conclusions: Intra-operative feedback leads to significant improvements in performance, however there is a paucity of research in this area. Further work is needed in order to establish the long-term benefits of feedback and the optimum means and circumstances of feedback delivery.

Article summary

- Intra-operative feedback leads to significant improvements in performance, however there is a paucity of research in this area.
- Further work is needed in order to establish the long-term benefits of feedback and the optimum means and circumstances of feedback delivery.

Strengths and limitations

- Systematic search ensuring no relevant studies were missed.
- Detailed extraction of data from studies.
- Very few relevant studies in the literature despite the importance of the topic.

INTRODUCTION

In light of increasing patient demands, costs and emphasis on safety, surgeons and their outcomes have become the subject of increased expectations and scrutiny (1). Coupled with this, time spent in the operating theatre by surgical trainees is declining worldwide due to regulations that have reduced the legal number of working hours (2, 3); this is particularly alarming in light of the now well-established relationship between surgical volume and surgical outcomes (4-6), and recent work has also directly linked intraoperative technical skill to complication and mortality rates (7). Such challenges necessitate increased efficiency of surgical training programmes such that an equivalent or superior level of surgical proficiency can be achieved in spite of the shorter length of time spent in the operating theatre.

One means by which surgical skills acquisition could be enhanced is via the dissemination of feedback on intra-operative performance. Studies in medical students performing basic surgical skills such as suturing, knot tying and basic laparoscopic tasks have demonstrated that feedback can improve skill acquisition (8-10). Additionally, proficiency in simulated laparoscopic salpingectomy is accelerated in medical students when they receive instructor feedback (11), and feedback improves colonoscopy performance in gastroenterologists (12). Thus, provision of feedback on intra-operative surgical performance to surgical trainees may also be associated with improved performance and/or a more rapid acquisition of skills, and hence formalised feedback should potentially serve as a key component of future surgical training programmes. Although feedback of intra-operative skill and technique can be a common occurrence in the operating theatre, the impact of this on performance, and requirements for optimal training have thus far not been reviewed. We therefore conducted a systematic review to evaluate the impact of feedback of intra-operative technical skill.

METHODS

Data Sources and Search strategy

A comprehensive search was undertaken to determine the impact of feedback on surgical performance via the Ovid SP interface. The following databases were searched from inception to February 2013: MEDLINE, Embase, PsycINFO, AMED and the Cochrane Database of Systematic Reviews.

We used two different domains of MeSH-terms and key words combined by "AND," and within each domain the terms were combined by "OR." The first domain contained terms related to surgical skill and performance while the second contained terms related to the impact of feedback. A detailed search strategy can be found in the Appendix. The search was limited to English publications with no other restrictions.

Study selection

Two reviewers independently reviewed citations and selected eligible studies based upon predetermined inclusion and exclusion criteria. Publications were selected for review if they satisfied the following inclusion criteria: article was published in a peer-reviewed journal; article described a study involving surgical patients or simulation; article investigated the impact of feedback of intra-operative surgical performance; article used a statistical unit that was patient-or procedure-focussed. The following exclusion criteria were applied to search results: the article was a conference abstract, editorial, letter, opinion, audit or review; the population studied was non-surgical (for example pathology, medicine); the article described methods of feedback, not the impact of feedback; the article utilised a medical student population. Two authors (MM, AT) independently examined all retrieved articles for inclusion. Any disagreement over inclusion or exclusion was resolved by consensus.

Data extraction

Thirty two data-points per study were extracted using a pre-designed data collection form including: first author, year of publication, study aim, study type, study design (e.g., prospective, retrospective, experimental, observational, cross-sectional, longitudinal), study population, population setting (e.g., hospital), surgical speciality, surgical procedure analysed, number of surgeons, types of feedback dissemination, content of feedback, frequency of feedback, measured outcomes and interventions following feedback. The full data extraction from the studies can be found in the Appendix.

RESULTS

Study identification and selection

Our search yielded 1,531 citations, of which 1,185 articles were excluded. After detailed evaluation of the 346 remaining articles, three studies remained eligible which comprised of a total of 280 procedures by 62 surgeons (13-15). A flow diagram of the search results is illustrated in **Figure 1**.

Study characteristics

All three studies were performed on surgical trainees, one involving live cholecystectomy cases, one involving simulated laparoscopic colectomy, and one involving simulated renal artery angioplasty. Two studies were two-armed RCTs (with one arm receiving feedback and the control arm receiving no feedback) (13, 15), whilst one study was a three-armed RCT (with one arm receiving expert feedback, another arm receiving non-expert feedback, and one arm receiving no feedback) (14). The studies included in this review are shown in in **Table 1** and their basic characteristics are summarised in **Table 2.**

Feedback dissemination

In all studies, feedback was delivered orally after each procedure (13-15). No written feedback was provided in any of the studies and one study required participants to self-assess their performance after each case in addition to receiving oral feedback (13). One study utilized video footage in facilitating feedback (15).

Feedback contents

The two examined studies involving simulation provided participants with feedback relevant to the exercise, including standard instrument metrics, procedural time and errors, accompanied with a description of correct methods where necessary (13, 14). For the study of live surgery, feedback was facilitated by review of a videotape recording of the operation, and a 60-minute structured feedback session, during which technical deficiencies and possible errors were covered and instructions for improvement offered (15). One study provided benchmarking relative to peers (13) and no studies provided surgeons with comparable data from the literature.

In one study, feedback was provided solely by a single surgeon with a large operative and teaching experience in laparoscopy (15). One study assessed the impact of expert (consultant surgeons) and non-expert (inexperienced surgical trainees) instructor feedback (14). There was found to be no difference between expert and non-expert feedback in all outcomes assessed other than error scores, which were lower when using the Vascular Interventional Surgical Trainer (VIST) error metrics and scoring during the operation (p=0.009) but not when a custom, more extensive scoring sheet which was completed by a single expert upon reviewing video footage of the procedures (14).

Impact of feedback

All three studies identified improvements in one or more of the outcomes assessed. **Table 3** shows outcomes assessed across the three studies with associated p-values. In addition, the study of simulated renal artery angioplasty assessed procedure-specific outcomes including contrast volume (mL), fluoroscopic time (seconds), balloon placement accuracy (mm), residual stenosis, and lesion coverage (%) (14). Of these, balloon placement accuracy was shown to be significantly improved in those receiving feedback (p = 0.041) (14). Although not reaching statistical significance, contrast volume utilised was 24.9 mL in control group, and 9.55 mL in those receiving feedback (14). Whilst not demonstrated via statistical methods, a smoother learning curve and earlier plateau in performance was noted in the group with feedback (14).

DISCUSSION

Our review included three studies assessing the impact of feedback of intra-operative surgical performance. Feedback was consistently found to be a powerful method for improving surgical performance in terms of operative metrics such as error scores and instrument movement metrics, as well as metrics specific to the procedure being undertaken. Feedback could thus represent a simple but powerful means by which efficiency and safety could be improved, thereby allowing for the attainment of surgical skills to a greater level of proficiency and/or in a shorter length of time in the context of training. This is of particular relevance as with the exception of video and virtual reality simulator training, training methods known to enhance performance in the operating theatre are few and far between (16, 17).

Only three studies were included in this review, reflecting the dearth of research in this area despite the significant benefits which feedback could bring; there seems to be many studies in the literature which describe how to assess or rate technical skill (18-20), but very few which actually assess how this data should be used.

All three studies were randomised controlled trials, however two of these three involved simulated, as opposed to live procedures (13, 14). Future studies should look to further assess the impact of feedback related to live surgery such that the broader implications of feedback can be appreciated.

The impact of feedback on long-term skill acquisition was not studied; all studies only assessed surgical performance with between 1 and 5 procedures after the first feedback was provided. Thus, studies taking place over a longer time scale are necessary. It is also important to establish the clinical significance of feedback; none of the studies included assessed whether the improvement in technical skill was associated with an improvement in clinical outcomes, although one might suspect it would, particularly in light of recent findings that technical skills rated by experts based on video footage correlates with surgical outcomes (7).

In one study, feedback included a review of a videotape recording and a 60-minute structured feedback session with a senior surgeon (15). Although extensive feedback sessions have been suggested (but not shown) to be effective (21), provision of feedback in this manner may be resource intensive and hence cost- and time-effectiveness must also be considered. However, given the fact that surgical trainees take longer than senior surgeons to complete procedures and also experience higher complication rates (22-26), even resource-demanding feedback, if effective, may at least partially pay for itself. The finding from a study involving simulation that non-expert delivered feedback is still effective (14), may broaden options for educationalists and time-pressed senior surgeons, although one must be careful not to implement counter-productive feedback initiatives.

Although there are few studies on this subject, all studies included in our analysis were randomized controlled trials, providing high quality evidence on the role of intraoperative feedback. Given the consistent benefit of feedback demonstrated, this supports further research on this topic and implementation of structured intraoperative feedback initiatives.

The small number of studies included in this review highlights the need for more substantive research in this area in order to establish the optimum means and circumstances of feedback dissemination such that standardised methods for future widespread implementation can be attained, and future studies should consider the effect of the following study variables:

1. Source (oral/written), facilitator (expert/non-expert), frequency (every procedure/once daily/weekly/monthly) and duration of feedback (months/years).
2. Surgeon involvement in feedback (either active or passive), standardised means of assessing surgical performance (which may be both generic and procedure-specific), content of feedback, timing of feedback relative to the procedure (intra-operatively/post-operatively), and the opportunities available for discussion, correction and learning.
3. Benchmarking (relative to both peers and literature data) and feedback based on intra-operative recordings reviewed at a later time-point.
4. Other interventions utilized, such as guidelines, education and review of instructional videos. The contributions of these interventions, and the additive effect they may have with feedback upon performance and outcomes are poorly understood.

It should also be borne in mind that in some circumstances or when delivered inappropriately, feedback may not be effective; for instance, although a number of studies in medical students have found feedback to improve acquisition of basic surgical skills (8-10), some have failed to find this (27), and the effect of feedback may plateau (28, 29).

In an era of increasing demands and scrutiny of surgeons in which surgical trainees are simultaneously spending less time in the operating theatre, methods to improve the efficiency of surgical performance are needed. The findings from this review suggest that feedback of intra-operative performance is an effective means by which this might be achieved; however despite the potential impact, there is a paucity of research in this area, and further work is needed in order to establish the optimum circumstances and means by which feedback can be delivered in a time- and cost-effective manner.

Table 1 – Overview of studies included and impact of feedback on performance

Reference	Country	Speciality	Surgical procedure	No. of participating surgeons	Total no. of cases	Study design
Boyle et al. 2011a (13)	Ireland	General	Simulated laparoscopic colectomy	28	5 per surgeon	RCT
Boyle et al. 2011b (14)	Ireland	General	Simulated renal artery angioplasty	18	6 per surgeon	RCT (three arms)
Grantcharov et al. 2007 (15)	Denmark	General	Cholecystectomy	16	2 per surgeon	RCT

Table 2 – Basic characteristics of studies included

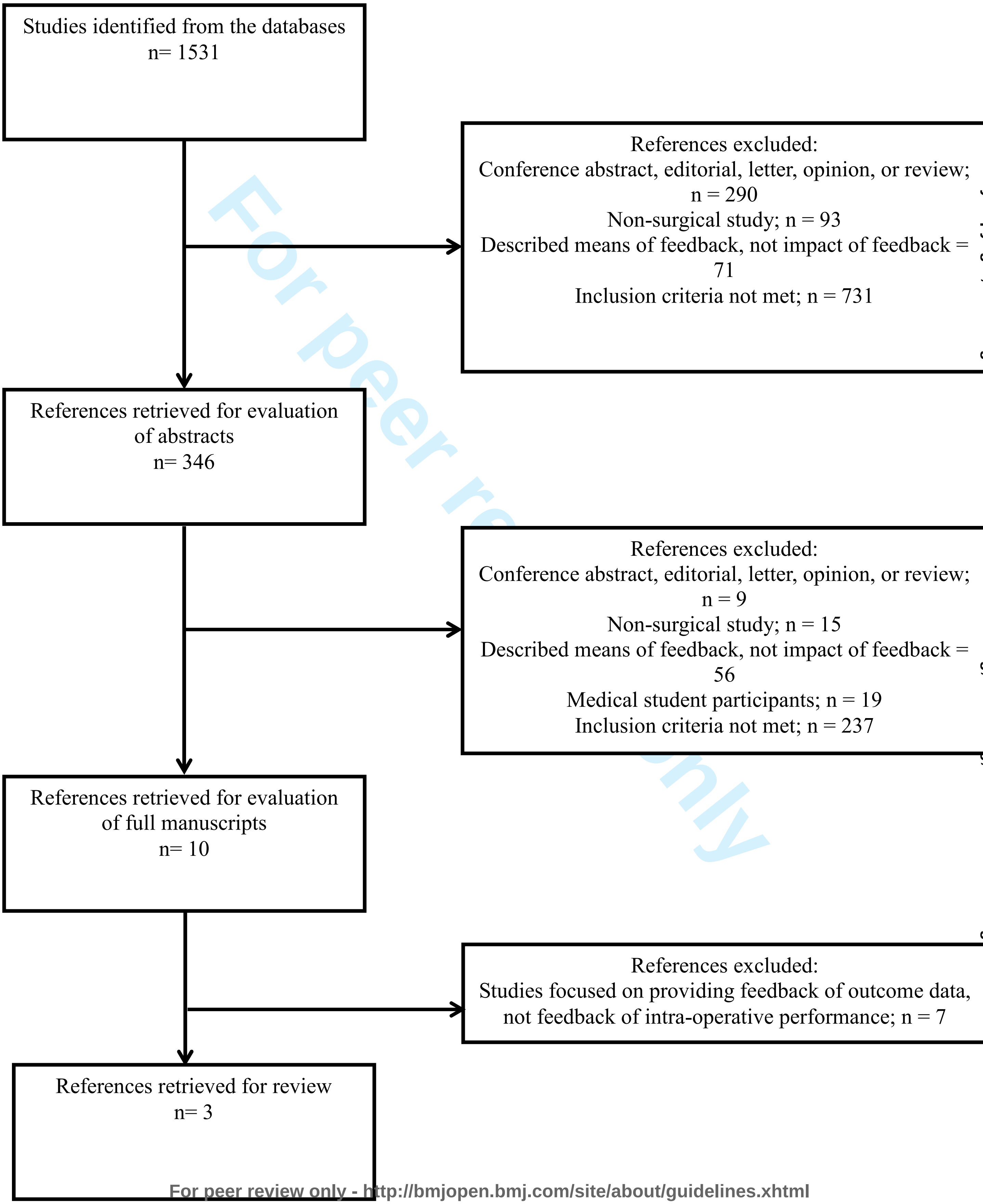
Study characteristics	No. of studies	References
All studies	3	(13-15)
Feedback dissemination		
-Oral	3	(13-15)
-Written	0	
-Self assessment	1	(13)
Feedback contents		
Outcomes	3	(13-15)
Benchmarking relative to peers	1	(13)
Comparable literature-reported figures	0	
Feedback frequency		
After each procedure	3	(13-15)
Video footage utilisation		
Assessment participant performance	2	(14, 15)
Dissemination of feedback	1	(15)

Table 3 – Key outcomes in included studies

Study	Procedure	Procedure time	Instrument path length	Instrument smoothness	Economy of movement	Error scores
Boyle et al. 2011a (13)	Simulated laparoscopic colectomy	-	0.001	0.045	-	<0.001
Boyle et al. 2011b (14)	Simulated renal artery angioplasty	ns	-	-	-	0.004
Grantcharov et al. 2007 (15)	Cholecystectomy	0.022	-	-	<0.001	0.003

'-' = outcome not assessed
'ns' = not significant
p-values shown are p-values for improvement in that outcome in feedback group when compared to control group with no feedback

Figure 1 – Identification of studies in this systematic review



Contributorship statement

AT, MM, ABV – systematic search, manuscript composition, proofing

MJC, PM – conception, design, drafting, proofing

Competing interests

The authors report no competing interests

Funding

Nil

Data sharing

The search criteria and data extracted from the studies is available in the appendix.

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Appendix: Search strategy

Databases:	**Ovid MEDLINE(R)**	<1948 to February Week 5 2013>
	Embase	<1980 to 2013 Week 06>
	AMED	<1985 to February 2013>
	PsycINFO	<1987 to February Week 1 2013>

Search Strategy via **Ovid SP** Interface:

1	surgical skill$.ti,ab,sh.	3419
2	surgical performance.ti,ab,sh.	947
3	surgical training.ti,ab,sh.	12533
4	surgical education.ti,ab,sh.	1627
5	surgical competenc$.ti,ab,sh.	362
6	surgical proficiency.ti,ab,sh.	106
7	surgical ability.ti,ab,sh.	52
8	surgical expertise.ti,ab,sh.	795
9	(surgeon$ adj4 performance).ti,ab.	864
10	(surgeon$ adj4 experience$).ti,ab.	16159
11	(surgeon$ adj4 assess$).ti,ab.	3064
12	(surgeon$ adj4 skill$).ti,ab.	2773
13	(surgeon$ adj4 individual).ti,ab.	1704
14	(surgeon$ adj4 learning).ti,ab.	1094
15	exp Specialties, surgical/mt, st	21043
16	exp Surgical procedures, operative/st	26882
17	or/1-16	85503
18	Feedback.ti,ab.	130446
19	Knowledge of results.ti,ab.	2075
20	Self-assessment.ti,ab.	11951
21	exp Employee Performance Appraisal/mt, st, sn	1290
22	exp Process Assessment/mt	369
23	or/18-22	145256
24	17 and 23	1514
25	limit 24 to english language	1451

Database: **Cochrane Database of Systematic Reviews** <2000 to 2012>

Search Strategy via **PubMed** Interface:

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1 Cochrane Database Syst Rev[Journal] AND (Surgery OR Surgeon OR Surgical) AND (Training OR Performance OR Skill OR Skills OR Competence OR Competency OR Proficiency OR Ability OR Expertise OR Learning Curve) AND (Feedback OR Knowledge of Results (Psychology) OR Self-Assessment OR Education, Medical, Continuing/methods)

Data extraction from reviewed studies

Study design

Author	Year	Surgical procedure	Prospective	Retrospective	Experimental	Observational	Cross-sectional	Longitudinal	Hospital setting	Study design
Boyle et al.	2011	Simulated laparoscopic colectomy	1	0	1	0	1	0	1	RCT
Boyle et al.	2011	Simulated renal artery angioplasty	1	0	1	0	1	0	1	RCT (three arms)
Grantcharov et. al	2007	Cholecystectomy	1	0	1	0	1	0	1	RCT

Study participants

Author	Year	Surgical procedure	Country	Participating surgeons	No. of surgeons in arm 1	No. of surgeons in arm 2	No. of surgeons in arm 3	Total number of surgeons	Proecedures per surgeon
Boyle et al.	2011	Simulated laparoscopic colectomy	Ireland	Surgical trainees	16	12		28	5
Boyle et al.	2011	Simulated renal artery angioplasty	Ireland	Surgical trainees	6	6	6	18	6
Grantcharov et. al	2007	Cholecystectomy	Denmark	Surgical trainees	8	8		16	2

Feedback

Author	Year	Surgical procedure	Feedback dissemination - written	Feedback dissemination - oral	Self-assessment	Video recording-assisted feedback dissemination	Peer benchmarking	Feedback provided with literature figures	Frequency: feedback after every procedure
Boyle et al.	2011	Simulated laparoscopic colectomy	0	1	1	0	1	0	1
Boyle et al.	2011	Simulated renal artery angioplasty	0	1	0	0	0	0	1
Grantcharov et. al	2007	Cholecystectomy	0	1	0	1	0	0	1

<u>**Outcomes and improvement**</u>

Author	Year	Surgical procedure	Video recording-assisted assessment of outcomes	Measured outcome - procedure time	Measured outcome - instrument path length	Measured outcome - instrument smoothness	Measured outcome - economy of movement	Measured outcome - error scores	Measured outcome - learning curves	Measured outcome - procedure specific measures	Feedback improved at least outcome
Boyle et al.	2011	Simulated laparoscopic colectomy	0	0	1	1	0	1	1	0	1
Boyle et al.	2011	Simulated renal artery angioplasty	1	1	0	0	0	1	0	1	1
Grantcharov et. al	2007	Cholecystectomy	1	1	0	0	1	1	0	0	1

BMJ Open

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Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-006759.R1
Article Type:	Research
Date Submitted by the Author:	15-Apr-2015
Complete List of Authors:	Trehan, Abhishek; University of Oxford, Maruthappu, Mahiben; Chair & Chief Executive's Office, NHS England Barnett-Vanes, Ashton; Imperial College London, Carty, Matthew; Harvard Medical School, McCulloch, Peter; University of Oxford,
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Financial Disclosure and Products Statement

None of the participating authors has a conflicting financial interest related to the work detailed in this manuscript, nor do any of the authors maintain a financial stake in any product, device or drug cited in this report.

ABSTRACT

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Results: Overall, feedback based on intra-operative surgical performance was found to be a powerful method for improving performance. In cholecystectomy, feedback led to a reduction in procedure time (p=0.022) and an improvement in economy of movement (p<0.001). In simulated laparoscopic colectomy, feedback led to improvements in instrument path length (p=0.001) and instrument smoothness (p=0.045). Feedback also reduced error scores in cholecystectomy (p=0.003), simulated laparoscopic colectomy (p<0.001) and simulated renal artery angioplasty (p=0.004). In addition, feedback improved balloon placement accuracy (p=0.041) and resulted in

a smoother learning curve and earlier plateau in performance in simulated renal artery angioplasty.

Conclusions: Intra-operative feedback appears to be associated with an improvement in performance, however there is a paucity of research in this area. Further work is needed in order to establish the long-term benefits of feedback and the optimum means and circumstances of feedback delivery.

Article summary

- Intra-operative feedback leads to significant improvements in performance, however there is a paucity of research in this area.
- Further work is needed in order to establish the long-term benefits of feedback and the optimum means and circumstances of feedback delivery.

Strengths and limitations

- Systematic review, minimising likelihood of relevant papers being missed.
- Detailed extraction of data from studies.
- Very few relevant studies in the literature despite the importance of the topic.

INTRODUCTION

In light of increasing patient demands, costs and emphasis on safety, surgeons and their outcomes have become the subject of increased expectations and scrutiny [1]. Coupled with this, time spent in the operating theatre by surgical trainees is declining worldwide due to regulations that have reduced the legal number of working hours [2, 3]; this is particularly alarming in light of the now well-established relationship between surgical volume and surgical outcomes [4-6], and recent work has also directly linked intraoperative technical skill to complication and mortality rates [7]. Such challenges necessitate increased efficiency of surgical training programmes such that an equivalent or superior level of surgical proficiency can be achieved in spite of the shorter length of time spent in the operating theatre.

One means by which surgical skills acquisition could be enhanced is via the dissemination of feedback on intra-operative performance. Studies in medical students performing basic surgical skills such as suturing, knot tying and basic laparoscopic tasks have demonstrated that feedback can improve skill acquisition [8-10]. Additionally, proficiency in simulated laparoscopic salpingectomy is accelerated in medical students when they receive instructor feedback [11], and feedback improves colonoscopy performance in gastroenterologists [12]. Thus, provision of feedback on intra-operative surgical performance to surgical trainees may also be associated with improved performance and/or a more rapid acquisition of skills, and hence formalised feedback should potentially serve as a key component of future surgical training programmes. Although feedback of intra-operative skill and technique can be a common occurrence in the operating theatre, the impact of this on performance, and requirements for optimal training have thus far not been reviewed. We therefore conducted a systematic review to evaluate the impact of feedback of technical skill in both the operating theatre and in the context of simulation.

METHODS

Data Sources and Search strategy

The systematic review was conducted in accordance with PRISMA guidelines. A comprehensive search was undertaken to determine the impact of feedback on surgical performance via the Ovid SP interface. The following databases were searched from inception to February 2013: MEDLINE, Embase, PsycINFO, AMED and the Cochrane Database of Systematic Reviews.

We used two different domains of MeSH-terms and key words combined by "AND," and within each domain the terms were combined by "OR." The first domain contained terms related to surgical skill and performance while the second contained terms related to the impact of feedback. A detailed search strategy can be found in the Appendix. The search was limited to English publications with no other restrictions.

Study selection

Two reviewers independently reviewed citations and selected eligible studies based upon predetermined inclusion and exclusion criteria. Publications were selected for review if they satisfied the following inclusion criteria: article was published in a peer-reviewed journal; article described a study involving surgical patients or simulation; article investigated the impact of feedback of intra-operative surgical performance; article used a statistical unit that was patient-or procedure-focussed. The following exclusion criteria were applied to search results: the article was a conference abstract, editorial, letter, opinion, audit or review; the population studied was non-surgical (for example pathology, medicine); the article described methods of feedback, not the impact of feedback; the article utilised a medical student population. Two authors (MM, AT) independently examined all retrieved articles for inclusion. Any disagreements over inclusion or exclusion were resolved by discussion between authors. References in relevant papers were also reviewed in order to identify any additional studies which may have been missed by the search strategy.

Data extraction

Thirty two data-points per study were extracted using a pre-designed data collection form including: first author, year of publication, study aim, study type, study design (e.g., prospective, retrospective, experimental, observational, cross-sectional, longitudinal), study population, population setting (e.g., hospital), surgical speciality, surgical procedure analysed, number of surgeons, types of feedback dissemination, content of feedback, frequency of feedback, measured outcomes and interventions following feedback. The full data extraction from the studies can be found in the Appendix.

RESULTS

Study identification and selection

Our search yielded 1,531 citations, of which 1,185 articles were excluded. After detailed evaluation of the 346 remaining articles, three studies remained eligible which comprised of a total of 280 procedures by 62 surgeons [13-15]. A flow diagram of the search results is illustrated in **Figure 1**.

Study characteristics

All three studies were performed on surgical trainees, one involving live cholecystectomy cases, one involving simulated laparoscopic colectomy, and one involving simulated renal artery angioplasty. Two studies were two-armed RCTs (with one arm receiving feedback and the control arm receiving no feedback) [13, 15], whilst one study was a three-armed RCT (with one arm receiving expert feedback, another arm receiving non-expert feedback, and one arm receiving no feedback) [14]. The studies included in this review are shown in in **Table 1** and their basic characteristics are summarised in **Table 2.**

Feedback dissemination

In all studies, feedback was delivered orally after each procedure [13-15]. No written feedback was provided in any of the studies and one study required participants to self-assess their performance after each case in addition to receiving oral feedback [13]. One study utilized video footage in facilitating feedback [15].

Feedback contents

The two examined studies involving simulation provided participants with feedback relevant to the exercise, including standard instrument metrics, procedural time and errors, accompanied with a description of correct methods where necessary [13, 14]. For the study of live surgery, feedback was facilitated by review of a videotape recording of the operation, and a 60-minute structured feedback session, during which technical deficiencies and possible errors were covered and instructions for improvement offered [15]. One study provided benchmarking relative to peers [13] and no studies provided surgeons with comparable data from the literature.

In one study, feedback was provided solely by a single surgeon with a large operative and teaching experience in laparoscopy [15]. One study assessed the impact of expert (consultant surgeons) and non-expert (inexperienced surgical trainees) instructor feedback [14]. There was found to be no difference between expert and non-expert feedback in all outcomes assessed other than error scores, which were lower when using the Vascular Interventional Surgical Trainer (VIST) error metrics and scoring during the operation (p=0.009) but not when a custom, more extensive scoring sheet which was completed by a single expert upon reviewing video footage of the procedures [14].

Impact of feedback

All three studies identified improvements in one or more of the outcomes assessed. **Table 3** shows outcomes assessed across the three studies with associated p-values. In addition, the study of simulated renal artery angioplasty assessed procedure-specific outcomes including contrast volume (mL), fluoroscopic time (seconds), balloon placement accuracy (mm), residual stenosis, and lesion coverage (%) [14]. Of these, balloon placement accuracy was shown to be significantly improved in those receiving feedback (p = 0.041) [14]. Although not reaching statistical significance, contrast volume utilised was 24.9 mL in control group, and 9.55 mL in those receiving feedback [14]. Whilst not demonstrated via statistical methods, a smoother learning curve and earlier plateau in performance was noted in the group with feedback [14].

DISCUSSION

Our review included three studies assessing the impact of feedback of intra-operative surgical performance. Feedback was consistently found to be a powerful method for improving surgical performance in terms of operative metrics such as error scores and instrument movement metrics, as well as metrics specific to the procedure being undertaken. Feedback could thus represent a simple but powerful means by which efficiency and safety could be improved, thereby allowing for the attainment of surgical skills to a greater level of proficiency and/or in a shorter length of time in the context of training. This is of particular relevance as with the exception of video and virtual reality simulator training, training methods known to enhance performance in the operating theatre are few and far between [16, 17].

Only three studies were included in this review, reflecting the dearth of research in this area despite the significant benefits which feedback could bring; there seems to be many studies in the literature which describe how to assess or rate technical skill [18-20], but very few which actually assess how this data should be used. It should be noted that a limitations of this study include that the search was conducted in Feb 2013, and that conference abstracts were excluded.

All three studies were randomised controlled trials, however two of these three involved simulated, as opposed to live procedures [13, 14]. Future studies should look to further assess the impact of feedback related to live surgery such that the broader implications of feedback can be appreciated.

The impact of feedback on long-term skill acquisition was not studied; all studies only assessed surgical performance with between 1 and 5 procedures after the first feedback was provided. Thus, studies taking place over a longer time scale are necessary. It is also important to establish the clinical significance of feedback; none of the studies included assessed whether the improvement in technical skill was associated with an improvement in clinical outcomes, although one might suspect it would, particularly in light of recent findings that technical skills rated by experts based on video footage correlates with surgical outcomes [7].

In one study, feedback included a review of a videotape recording and a 60-minute structured feedback session with a senior surgeon [15]. Although extensive feedback sessions have been suggested (but not shown) to be effective [21], provision of feedback in this manner may be resource intensive and hence cost- and time-effectiveness must also be considered. The finding from a study involving simulation that non-expert delivered feedback is still effective [14], may broaden options for educationalists and time-pressed senior surgeons, although one must be careful not to implement counter-productive feedback initiatives.

Although there are few studies on this subject, all studies included in our analysis were randomized controlled trials, providing high quality evidence on the role of intraoperative feedback. Given the consistent benefit of feedback demonstrated, this supports further research on this topic and implementation of structured intraoperative feedback initiatives.

The small number of studies included in this review highlights the need for more substantive research in this area in order to establish the optimum means and circumstances of feedback dissemination such that standardised methods for future widespread implementation can be attained, and future studies should consider the effect of the following study variables:

1. Source (oral/written), facilitator (expert/non-expert), frequency (every procedure/once daily/weekly/monthly) and duration of feedback (months/years).
2. Surgeon involvement in feedback (either active or passive), standardised means of assessing surgical performance (which may be both generic and procedure-specific), content of feedback, timing of feedback relative to the procedure (intra-operatively/post-operatively), and the opportunities available for discussion, correction and learning.
3. Benchmarking (relative to both peers and literature data) and feedback based on intra-operative recordings reviewed at a later time-point.
4. Other interventions utilized, such as guidelines, education and review of instructional videos. The contributions of these interventions, and the additive effect they may have with feedback upon performance and outcomes are poorly understood.

It should also be borne in mind that in some circumstances or when delivered inappropriately, feedback may not be effective; for instance, although a number of studies in medical students have found feedback to improve acquisition of basic surgical skills [8-10], some have failed to find this [22], and the effect of feedback may plateau [23, 24]. Frameworks have been suggested in order to ensure appropriate dissemination of feedback [25], which is particularly important given the fact that trainees often feel they are provided with inadequate feedback despite senior surgeons feeling their feedback provision is adequate [26, 27].

In an era of increasing demands and scrutiny of surgeons in which surgical trainees are simultaneously spending less time in the operating theatre, methods to improve the efficiency of surgical performance are needed. The findings from this review suggest that feedback of intra-operative performance is an effective means by which this might be achieved; however despite the potential impact, there is a paucity of research in this area, and further work is needed in order to establish the optimum circumstances and means by which feedback can be delivered in a time- and cost-effective manner.

Table 1 – Overview of studies included and impact of feedback on performance

Reference	Country	Speciality	Surgical procedure	No. of participating surgeons	Total no. of cases	Study design
Boyle et al. 2011a [13]	Ireland	General surgery	Simulated laparoscopic colectomy	28	5 per surgeon	RCT
Boyle et al. 2011b [14]	Ireland	General surgery	Simulated renal artery angioplasty	18	6 per surgeon	RCT (three arms)
Grantcharov et al. 2007 [15]	Denmark	General surgery	Cholecystectomy	16	2 per surgeon	RCT

Table 2 – Basic characteristics of studies included

Study characteristics	No. of studies	References
All studies	3	[13-15]
Feedback dissemination		
-Oral	3	[13-15]
-Written	0	
-Self assessment	1	[13]
Feedback contents		
Outcomes	3	[13-15]
Benchmarking relative to peers	1	[13]
Comparable literature-reported figures	0	
Feedback frequency		
After each procedure	3	[13-15]
Video footage utilisation		
Assessment participant performance	2	[14, 15]
Dissemination of feedback	1	[15]

Table 3 – Key outcomes in included studies

Study	Procedure	Procedure time	Instrument path length	Instrument smoothness	Economy of movement	Error scores
Boyle et al. 2011a [13]	Simulated laparoscopic colectomy	-	0.001	0.045	-	<0.001
Boyle et al. 2011b [14]	Simulated renal artery angioplasty	ns	-	-	-	0.004
Grantcharov et al. 2007 [15]	Cholecystectomy	0.022	-	-	<0.001	0.003

'-' = outcome not assessed
'ns' = not significant
p-values shown are p-values for improvement in that outcome in feedback group when compared to control group with no feedback

Contributorship statement

AT, MM, ABV – systematic search, manuscript composition, proofing

MJC, PM – conception, design, drafting, proofing

Competing interests

The authors report no competing interests

Funding

Nil

Data sharing

The search criteria and data extracted from the studies is available in the appendix.

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Figure 1 – Identification of studies in this systematic review

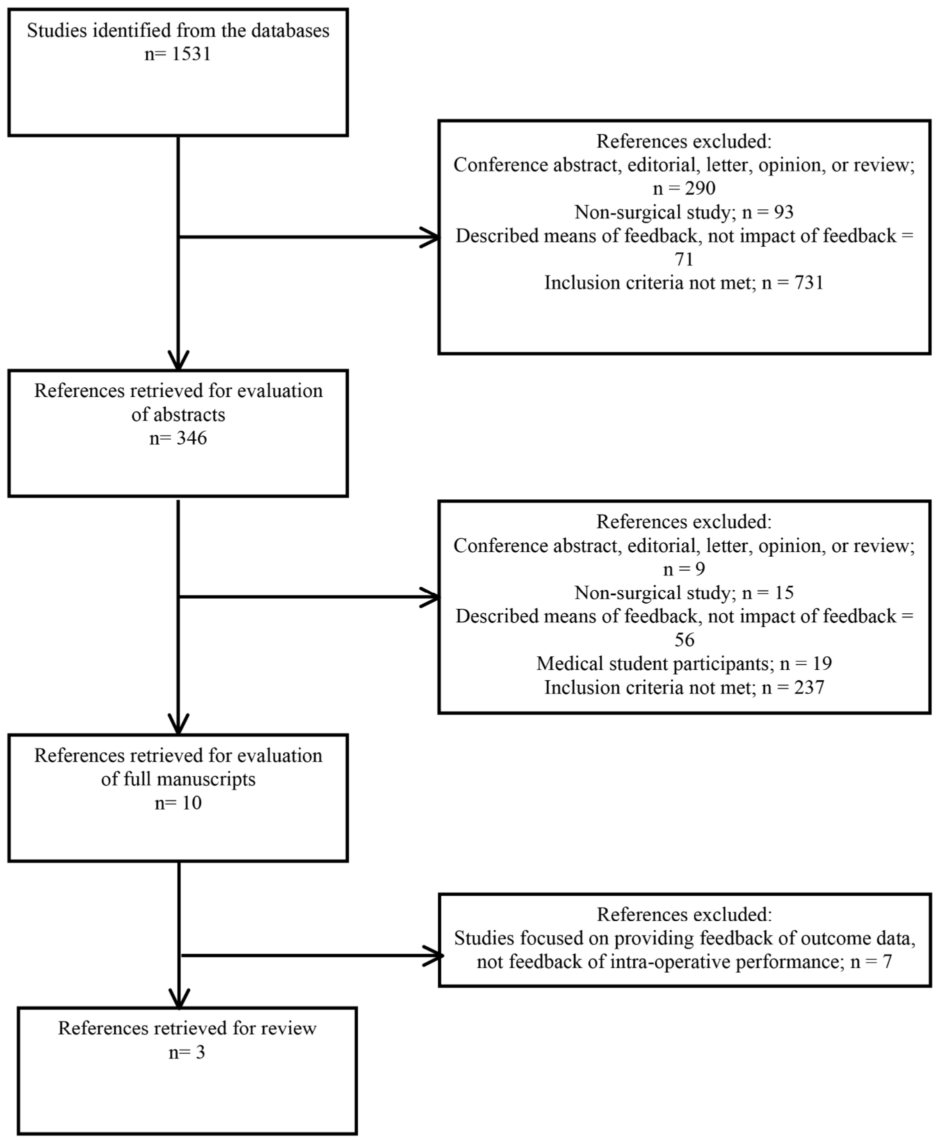

Fig 1
191x247mm (300 x 300 DPI)

Appendix: Search strategy

Databases:	**Ovid MEDLINE(R)**	<1948 to February Week 5 2013>
	Embase	<1980 to 2013 Week 06>
	AMED	<1985 to February 2013>
	PsycINFO	<1987 to February Week 1 2013>

Search Strategy via **Ovid SP** Interface:

1	surgical skill$.ti,ab,sh.	3419
2	surgical performance.ti,ab,sh.	947
3	surgical training.ti,ab,sh.	12533
4	surgical education.ti,ab,sh.	1627
5	surgical competenc$.ti,ab,sh.	362
6	surgical proficiency.ti,ab,sh.	106
7	surgical ability.ti,ab,sh.	52
8	surgical expertise.ti,ab,sh.	795
9	(surgeon$ adj4 performance).ti,ab.	864
10	(surgeon$ adj4 experience$).ti,ab.	16159
11	(surgeon$ adj4 assess$).ti,ab.	3064
12	(surgeon$ adj4 skill$).ti,ab.	2773
13	(surgeon$ adj4 individual).ti,ab.	1704
14	(surgeon$ adj4 learning).ti,ab.	1094
15	exp Specialties, surgical/mt, st	21043
16	exp Surgical procedures, operative/st	26882
17	or/1-16	85503
18	Feedback.ti,ab.	130446
19	Knowledge of results.ti,ab.	2075
20	Self-assessment.ti,ab.	11951
21	exp Employee Performance Appraisal/mt, st, sn	1290
22	exp Process Assessment/mt	369
23	or/18-22	145256
24	17 and 23	1514
25	limit 24 to english language	1451

Database: **Cochrane Database of Systematic Reviews** <2000 to 2012>

Search Strategy via **PubMed** Interface:

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1 Cochrane Database Syst Rev[Journal] AND (Surgery OR Surgeon OR Surgical) AND (Training OR Performance OR Skill OR Skills OR Competence OR Competency OR Proficiency OR Ability OR Expertise OR Learning Curve) AND (Feedback OR Knowledge of Results (Psychology) OR Self-Assessment OR Education, Medical, Continuing/methods)

Data extraction from reviewed studies

Study design

Author	Year	Surgical procedure	Prospective	Retrospective	Experimental	Observational	Cross-sectional	Longitudinal	Hospital setting	Study design
Boyle et al.	2011	Simulated laparoscopic colectomy	1	0	1	0	1	0	1	RCT
Boyle et al.	2011	Simulated renal artery angioplasty	1	0	1	0	1	0	1	RCT (three arms)
Grantcharov et. al	2007	Cholecystectomy	1	0	1	0	1	0	1	RCT

Study participants

Author	Year	Surgical procedure	Country	Participating surgeons	No. of surgeons in arm 1	No. of surgeons in arm 2	No. of surgeons in arm 3	Total number of surgeons	Proecedures per surgeon
Boyle et al.	2011	Simulated laparoscopic colectomy	Ireland	Surgical trainees	16	12		28	5
Boyle et al.	2011	Simulated renal artery angioplasty	Ireland	Surgical trainees	6	6	6	18	6
Grantcharov et. al	2007	Cholecystectomy	Denmark	Surgical trainees	8	8		16	2

Feedback

Author	Year	Surgical procedure	Feedback dissemination - written	Feedback dissemination - oral	Self-assessment	Video recording-assisted feedback dissemination	Peer benchmarking	Feedback provided with literature figures	Frequency: feedback after every procedure
Boyle et al.	2011	Simulated laparoscopic colectomy	0	1	1	0	1	0	1
Boyle et al.	2011	Simulated renal artery angioplasty	0	1	0	0	0	0	1
Grantcharov et. al	2007	Cholecystectomy	0	1	0	1	0	0	1

Outcomes and improvement

Author	Year	Surgical procedure	Video recording-assisted assessment of outcomes	Measured outcome - procedure time	Measured outcome - instrument path length	Measured outcome - instrument smoothness	Measured outcome - economy of movement	Measured outcome - error scores	Measured outcome - learning curves	Measured outcome - procedure specific measures	Feedback improved at least outcome
Boyle et al.	2011	Simulated laparoscopic colectomy	0	0	1	1	0	1	1	0	1
Boyle et al.	2011	Simulated renal artery angioplasty	1	1	0	0	0	1	0	1	1
Grantcharov et. al	2007	Cholecystectomy	1	1	0	0	1	1	0	0	1

BMJ Open

THE IMPACT OF FEEDBACK OF INTRA-OPERATIVE TECHNICAL PERFORMANCE IN SURGERY: A SYSTEMATIC REVIEW

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-006759.R2
Article Type:	Research
Date Submitted by the Author:	28-Apr-2015
Complete List of Authors:	Trehan, Abhishek; University of Oxford, Barnett-Vanes, Ashton; Imperial College London, Carty, Matthew; Harvard Medical School, McCulloch, Peter; University of Oxford, Maruthappu, Mahiben; Imperial College London,
Primary Subject Heading:	Surgery
Secondary Subject Heading:	Medical education and training
Keywords:	Feedback, Quality improvement, performance

THE IMPACT OF FEEDBACK OF INTRA-OPERATIVE TECHNICAL PERFORMANCE IN SURGERY: A SYSTEMATIC REVIEW

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Word count: 2028

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Financial Disclosure and Products Statement

None of the participating authors has a conflicting financial interest related to the work detailed in this manuscript, nor do any of the authors maintain a financial stake in any product, device or drug cited in this report.

ABSTRACT

Objectives: Increasing patient demands, costs and emphasis on safety coupled with reductions in the length of time surgical trainees spend in the operating theatre necessitate means to improve the efficiency of surgical training. In this respect, feedback based on intra-operative surgical performance may be beneficial. Our aim was to systematically review the impact of intra-operative feedback based on surgical performance.

Setting: MEDLINE, Embase, PsycINFO, AMED and the Cochrane Database of Systematic Reviews were searched. Two reviewers independently reviewed citations using predetermined inclusion and exclusion criteria. 32 data-points per study were extracted.

Participants: The search strategy yielded 1,531 citations. Three studies were eligible, which comprised a total of 280 procedures by 62 surgeons

Results: Overall, feedback based on intra-operative surgical performance was found to be a powerful method for improving performance. In cholecystectomy, feedback led to a reduction in procedure time ($p=0.022$) and an improvement in economy of movement ($p<0.001$). In simulated laparoscopic colectomy, feedback led to improvements in instrument path length ($p=0.001$) and instrument smoothness ($p=0.045$). Feedback also reduced error scores in cholecystectomy ($p=0.003$), simulated laparoscopic colectomy ($p<0.001$) and simulated renal artery angioplasty ($p=0.004$). In addition, feedback improved balloon placement accuracy ($p=0.041$) and resulted in

a smoother learning curve and earlier plateau in performance in simulated renal artery angioplasty.

Conclusions: Intra-operative feedback appears to be associated with an improvement in performance, however there is a paucity of research in this area. Further work is needed in order to establish the long-term benefits of feedback and the optimum means and circumstances of feedback delivery.

Key words: surgery, feedback, surgical education, surgical training

Article summary

- Intra-operative feedback leads to significant improvements in performance, however there is a paucity of research in this area.
- Further work is needed in order to establish the long-term benefits of feedback and the optimum means and circumstances of feedback delivery.

Strengths and limitations

- Systematic review, minimising likelihood of relevant papers being missed.
- Detailed extraction of data from studies.
- Very few relevant studies in the literature despite the importance of the topic.

INTRODUCTION

In light of increasing patient demands, costs and emphasis on safety, surgeons and their outcomes have become the subject of increased expectations and scrutiny [1]. Coupled with this, time spent in the operating theatre by surgical trainees is declining worldwide due to regulations that have reduced the legal number of working hours [2, 3]; this is particularly alarming in light of the now well-established relationship between surgical volume and surgical outcomes [4-6], and recent work has also directly linked intraoperative technical skill to complication and mortality rates [7]. Such challenges necessitate increased efficiency of surgical training programmes such that an equivalent or superior level of surgical proficiency can be achieved in spite of the shorter length of time spent in the operating theatre.

One means by which surgical skills acquisition could be enhanced is via the dissemination of feedback on intra-operative performance. Studies in medical students performing basic surgical skills such as suturing, knot tying and basic laparoscopic tasks have demonstrated that feedback can improve skill acquisition [8-10]. Additionally, proficiency in simulated laparoscopic salpingectomy is accelerated in medical students when they receive instructor feedback [11], and feedback improves colonoscopy performance in gastroenterologists [12]. Thus, provision of feedback on intra-operative surgical performance to surgical trainees may also be associated with improved performance and/or a more rapid acquisition of skills, and hence formalised feedback should potentially serve as a key component of future surgical training programmes. Although feedback of intra-operative skill and technique can be a common occurrence in the operating theatre, the impact of this on performance, and requirements for optimal training have thus far not been reviewed. We therefore conducted a systematic review to evaluate the impact of feedback of technical skill in both the operating theatre and in the context of simulation. For the purpose of this study, feedback was defined as the provision of information pertaining to the operator's surgical performance with the aim of improving subsequent performance.

METHODS

Data Sources and Search strategy

The systematic review was conducted in accordance with PRISMA guidelines. A comprehensive search was undertaken to determine the impact of feedback on surgical performance via the Ovid SP interface. The following databases were searched from inception to February 2013: MEDLINE, Embase, PsycINFO, AMED and the Cochrane Database of Systematic Reviews.

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Data extraction

Thirty two data-points per study were extracted using a pre-designed data collection form including: first author, year of publication, study aim, study type, study design (e.g., prospective, retrospective, experimental, observational, cross-sectional, longitudinal), study population, population setting (e.g., hospital), surgical speciality, surgical procedure analysed, number of surgeons, types of feedback dissemination, content of feedback, frequency of feedback, measured outcomes and interventions following feedback. The full data extraction from the studies can be found in Appendix 2.

RESULTS

Study identification and selection

Our search yielded 1,531 citations, of which 1,185 articles were excluded. After detailed evaluation of the 346 remaining articles, three studies remained eligible which comprised of a total of 280 procedures by 62 surgeons [13-15]. A flow diagram of the search results is illustrated in **Figure 1**.

Study characteristics

All three studies were performed on surgical trainees, one involving live cholecystectomy cases, one involving simulated laparoscopic colectomy, and one involving simulated renal artery angioplasty. Two studies were two-armed RCTs (with one arm receiving feedback and the control arm receiving no feedback) [13, 15], whilst one study was a three-armed RCT (with one arm receiving expert feedback, another arm receiving non-expert feedback, and one arm receiving no feedback) [14]. The studies included in this review are shown in in **Table 1** and their basic characteristics are summarised in **Table 2.**

Feedback dissemination

In all studies, feedback was delivered orally after each procedure [13-15]. No written feedback was provided in any of the studies and one study required participants to self-assess their performance after each case in addition to receiving oral feedback [13]. One study utilized video footage in facilitating feedback [15].

Feedback contents

The two examined studies involving simulation provided participants with feedback relevant to the exercise, including standard instrument metrics, procedural time and errors, accompanied with a description of correct methods where necessary [13, 14]. For the study of live surgery, feedback was facilitated by review of a videotape recording of the operation, and a 60-minute structured feedback session, during which technical deficiencies and possible errors were covered and instructions for improvement offered [15]. One study provided benchmarking relative to peers [13] and no studies provided surgeons with comparable data from the literature.

In one study, feedback was provided solely by a single surgeon with a large operative and teaching experience in laparoscopy [15]. One study assessed the impact of expert (consultant surgeons) and non-expert (inexperienced surgical trainees) instructor feedback [14]. There was found to be no difference between expert and non-expert feedback in all outcomes assessed other than error scores, which were lower when using the Vascular Interventional Surgical Trainer (VIST) error metrics and scoring during the operation (p=0.009) but not when a custom, more extensive scoring sheet which was completed by a single expert upon reviewing video footage of the procedures [14].

Impact of feedback

All three studies identified improvements in one or more of the outcomes assessed. **Table 3** shows outcomes assessed across the three studies with associated p-values. In addition, the study of simulated renal artery angioplasty assessed procedure-specific outcomes including contrast volume (mL), fluoroscopic time (seconds), balloon placement accuracy (mm), residual stenosis, and lesion coverage (%) [14]. Of these, balloon placement accuracy was shown to be significantly improved in those receiving feedback (p = 0.041) [14]. Although not reaching statistical significance, contrast volume utilised was 24.9 mL in control group, and 9.55 mL in those receiving feedback [14]. Whilst not demonstrated via statistical methods, a smoother learning curve and earlier plateau in performance was noted in the group with feedback [14].

DISCUSSION

Our review included three studies assessing the impact of feedback of intra-operative surgical performance. Feedback was consistently found to be a powerful method for improving surgical performance in terms of operative metrics such as error scores and instrument movement metrics, as well as metrics specific to the procedure being undertaken. Feedback could thus represent a simple but powerful means by which efficiency and safety could be improved, thereby allowing for the attainment of surgical skills to a greater level of proficiency and/or in a shorter length of time in the context of training. This is of particular relevance as with the exception of video and virtual reality simulator training, training methods known to enhance performance in the operating theatre are few and far between [16, 17].

Only three studies were included in this review, reflecting the dearth of research in this area despite the significant benefits which feedback could bring; there seems to be many studies in the literature which describe how to assess or rate technical skill [18-20], but very few which actually assess how this data should be used. Limitations of this study include that the search was conducted in Feb 2013, that conference abstracts were excluded, and that study quality was not formally assessed.

All three studies were randomised controlled trials, however two of these three involved simulated, as opposed to live procedures [13, 14]. Future studies should look to further assess the impact of feedback related to live surgery such that the broader implications of feedback can be appreciated.

The impact of feedback on long-term skill acquisition was not studied; all studies only assessed surgical performance with between 1 and 5 procedures after the first feedback was provided. Thus, studies taking place over a longer time scale are necessary. It is also important to establish the clinical significance of feedback; none of the studies included assessed whether the improvement in technical skill was associated with an improvement in clinical outcomes, although one might suspect it would, particularly in light of recent findings that technical skills rated by experts based on video footage correlates with surgical outcomes [7].

In one study, feedback included a review of a videotape recording and a 60-minute structured feedback session with a senior surgeon [15]. Although extensive feedback sessions have been suggested (but not shown) to be effective [21], provision of feedback in this manner may be resource intensive and hence cost- and time-effectiveness must also be considered. The finding from a study involving simulation that non-expert delivered feedback is still effective [14], may broaden options for educationalists and time-pressed senior surgeons, although one must be careful not to implement counter-productive feedback initiatives.

Although there are few studies on this subject, all studies included in our analysis were randomised controlled trials. Given the consistent benefit of feedback demonstrated, this supports further research on this topic and implementation of structured intraoperative feedback initiatives.

The small number of studies included in this review highlights the need for more substantive research in this area in order to establish the optimum means and circumstances of feedback dissemination such that standardised methods for future widespread implementation can be attained, and future studies should consider the effect of the following study variables:

1. Source (oral/written), facilitator (expert/non-expert), frequency (every procedure/once daily/weekly/monthly) and duration of feedback (months/years).
2. Surgeon involvement in feedback (either active or passive), standardised means of assessing surgical performance (which may be both generic and procedure-specific), content of feedback, timing of feedback relative to the procedure (intra-operatively/post-operatively), and the opportunities available for discussion, correction and learning.
3. Benchmarking (relative to both peers and literature data) and feedback based on intra-operative recordings reviewed at a later time-point.
4. Other interventions utilized, such as guidelines, education and review of instructional videos. The contributions of these interventions, and the additive effect they may have with feedback upon performance and outcomes are poorly understood.

It should also be borne in mind that in some circumstances or when delivered inappropriately, feedback may not be effective; for instance, although a number of studies in medical students have found feedback to improve acquisition of basic surgical skills [8-10], some have failed to find this [22], and the effect of feedback may plateau [23, 24]. Frameworks have been suggested in order to ensure appropriate dissemination of feedback [25], which is particularly important given the fact that trainees often feel they are provided with inadequate feedback despite senior surgeons feeling their feedback provision is adequate [26, 27].

In an era of increasing demands and scrutiny of surgeons in which surgical trainees are simultaneously spending less time in the operating theatre, methods to improve the efficiency of surgical performance are needed. The findings from this review suggest that feedback of intra-operative performance is an effective means by which this might be achieved; however despite the potential impact, there is a paucity of research in this area, and further work is needed in order to establish the optimum circumstances and means by which feedback can be delivered in a time- and cost-effective manner.

Table 1 – Overview of studies included and impact of feedback on performance

Reference	Country	Speciality	Surgical procedure	No. of participating surgeons	Total no. of cases	Study design
Boyle et al. 2011a [13]	Ireland	General surgery	Simulated laparoscopic colectomy	28	5 per surgeon	RCT
Boyle et al. 2011b [14]	Ireland	General surgery	Simulated renal artery angioplasty	18	6 per surgeon	RCT (three arms)
Grantcharov et al. 2007 [15]	Denmark	General surgery	Cholecystectomy	16	2 per surgeon	RCT

Table 2 – Basic characteristics of studies included

Study characteristics	No. of studies	References
All studies	3	[13-15]
Feedback dissemination		
-Oral	3	[13-15]
-Written	0	
-Self assessment	1	[13]
Feedback contents		
Outcomes	3	[13-15]
Benchmarking relative to peers	1	[13]
Comparable literature-reported figures	0	
Feedback frequency		
After each procedure	3	[13-15]
Video footage utilisation		
Assessment participant performance	2	[14, 15]
Dissemination of feedback	1	[15]

Table 3 – Key outcomes in included studies

Study	Procedure	Procedure time	Instrument path length	Instrument smoothness	Economy of movement	Error scores
Boyle et al. 2011a [13]	Simulated laparoscopic colectomy	-	0.001	0.045	-	<0.001
Boyle et al. 2011b [14]	Simulated renal artery angioplasty	ns	-	-	-	0.004
Grantcharov et al. 2007 [15]	Cholecystectomy	0.022	-	-	<0.001	0.003

'-' = outcome not assessed
'ns' = not significant
p-values shown are p-values for improvement in that outcome in feedback group when compared to control group with no feedback

Contributorship statement

AT, MM, ABV – systematic search, manuscript composition, proofing

MJC, PM – conception, design, drafting, proofing

Competing interests

The authors report no competing interests

Funding

Nil

Data sharing

The search criteria and data extracted from the studies is available in the Appendices.

FIGURE LEGENDS

Figure 1 – Summary of search strategy for identification of relevant studies

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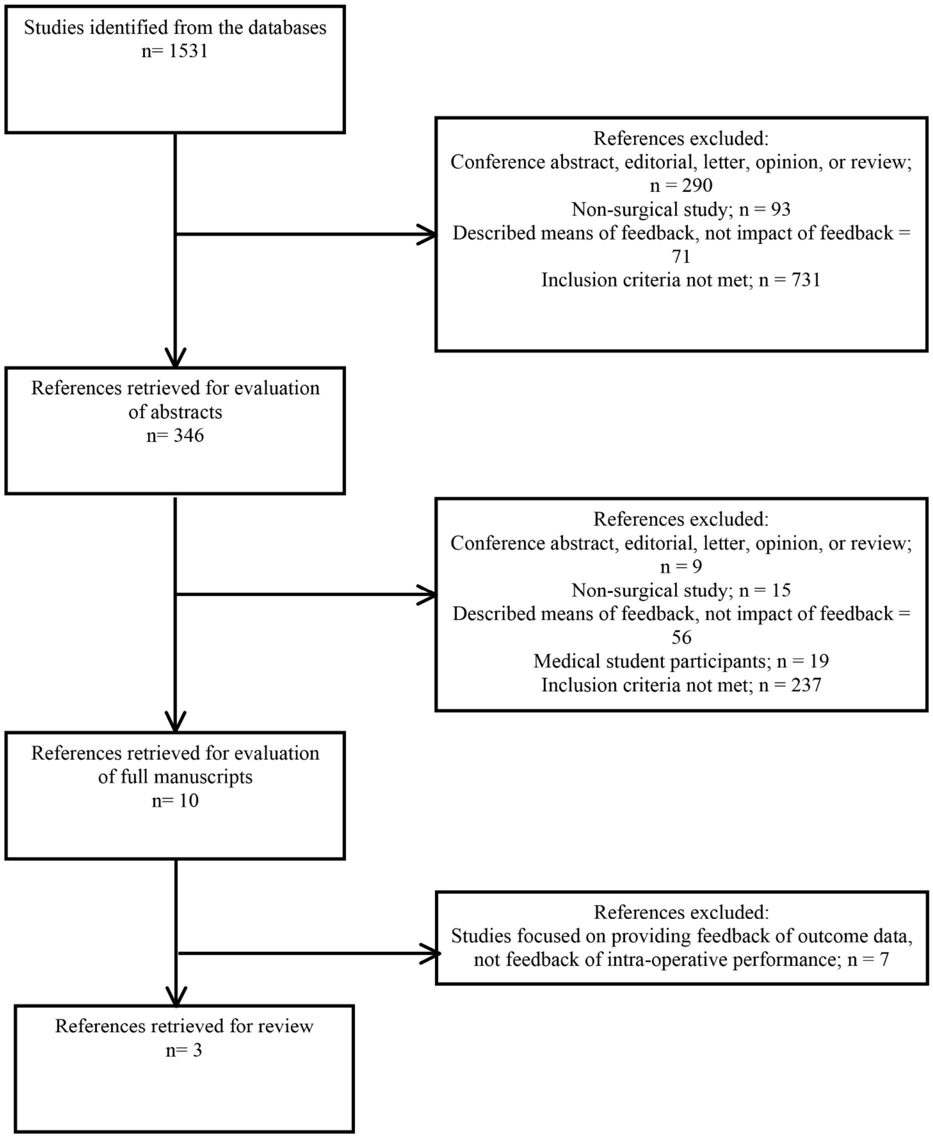
Figure 1



191x247mm (300 x 300 DPI)

Appendix: Search strategy

Databases:	**Ovid MEDLINE(R)**	<1948 to February Week 5 2013>
	Embase	<1980 to 2013 Week 06>
	AMED	<1985 to February 2013>
	PsycINFO	<1987 to February Week 1 2013>

Search Strategy via **Ovid SP** Interface:

1	surgical skill$.ti,ab,sh.	3419
2	surgical performance.ti,ab,sh.	947
3	surgical training.ti,ab,sh.	12533
4	surgical education.ti,ab,sh.	1627
5	surgical competenc$.ti,ab,sh.	362
6	surgical proficiency.ti,ab,sh.	106
7	surgical ability.ti,ab,sh.	52
8	surgical expertise.ti,ab,sh.	795
9	(surgeon$ adj4 performance).ti,ab.	864
10	(surgeon$ adj4 experience$).ti,ab.	16159
11	(surgeon$ adj4 assess$).ti,ab.	3064
12	(surgeon$ adj4 skill$).ti,ab.	2773
13	(surgeon$ adj4 individual).ti,ab.	1704
14	(surgeon$ adj4 learning).ti,ab.	1094
15	exp Specialties, surgical/mt, st	21043
16	exp Surgical procedures, operative/st	26882
17	or/1-16	85503
18	Feedback.ti,ab.	130446
19	Knowledge of results.ti,ab.	2075
20	Self-assessment.ti,ab.	11951
21	exp Employee Performance Appraisal/mt, st, sn	1290
22	exp Process Assessment/mt	369
23	or/18-22	145256
24	17 and 23	1514
25	limit 24 to english language	1451

Database: **Cochrane Database of Systematic Reviews** <2000 to 2012>

Search Strategy via **PubMed** Interface:

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1 Cochrane Database Syst Rev[Journal] AND (Surgery OR Surgeon OR Surgical) AND (Training OR Performance OR Skill OR Skills OR Competence OR Competency OR Proficiency OR Ability OR Expertise OR Learning Curve) AND (Feedback OR Knowledge of Results (Psychology) OR Self-Assessment OR Education, Medical, Continuing/methods)

Data extraction from reviewed studies

Study design

Author	Year	Surgical procedure	Prospective	Retrospective	Experimental	Observational	Cross-sectional	Longitudinal	Hospital setting	Study design
Boyle et al.	2011	Simulated laparoscopic colectomy	1	0	1	0	1	0	1	RCT
Boyle et al.	2011	Simulated renal artery angioplasty	1	0	1	0	1	0	1	RCT (three arms)
Grantcharov et. al	2007	Cholecystectomy	1	0	1	0	1	0	1	RCT

Study participants

Author	Year	Surgical procedure	Country	Participating surgeons	No. of surgeons in arm 1	No. of surgeons in arm 2	No. of surgeons in arm 3	Total number of surgeons	Proecedures per surgeon
Boyle et al.	2011	Simulated laparoscopic colectomy	Ireland	Surgical trainees	16	12		28	5
Boyle et al.	2011	Simulated renal artery angioplasty	Ireland	Surgical trainees	6	6	6	18	6
Grantcharov et. al	2007	Cholecystectomy	Denmark	Surgical trainees	8	8		16	2

Feedback

Author	Year	Surgical procedure	Feedback dissemination - written	Feedback dissemination - oral	Self-assessment	Video recording assisted feedback dissemination	Peer benchmarking	Feedback provided with literature figures	Frequency: feedback after every procedure
Boyle et al.	2011	Simulated laparoscopic colectomy	0	1	1	0	1	0	1
Boyle et al.	2011	Simulated renal artery angioplasty	0	1	0	0	0	0	1
Grantcharov et. al	2007	Cholecystectomy	0	1	0	1	0	0	1

Outcomes and improvement

Author	Year	Surgical procedure	Video recording-assisted assessment of outcomes	Measured outcome - procedure time	Measured outcome - instrument path length	Measured outcome - instrument smoothness	Measured outcome economy of movement	Measured outcome - error scores	Measured outcome - learning curves	Measured outcome - procedure specific measures	Feedback improved at least outcome
Boyle et al.	2011	Simulated laparoscopic colectomy	0	0	1	1	0	1	1	0	1
Boyle et al.	2011	Simulated renal artery angioplasty	1	1	0	0	0	1	0	1	1
Grantcharov et. al	2007	Cholecystectomy	1	1	0	0	0	1	0	0	1

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5-6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	NA
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6-7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6-7, APPENDIX
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	6-7, APPENDIX
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6-7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6-7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6-7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	NA
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	NA; variable outcomes

PRISMA 2009 Checklist

Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA; results not suitable for combination

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	6-7
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	17
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	6-7
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	NA
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	16
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	NA
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	NA
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA; results not suitable for combination
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	10-13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	10-13
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	10-13
FUNDING			

PRISMA 2009 Checklist

Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA: no funding

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

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