Incidence of sternal wound infection after tracheostomy in patients undergoing cardiac surgery: A systematic review and meta-analysis

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ABSTRACT

Purpose: This systematic review and meta-analysis was performed to determine whether timing or type of tracheostomy was associated with superficial or deep sternal wound infections after cardiac surgery.

Methods: All studies reporting the incidence of sternal wound infection after tracheostomy in patients undergoing cardiac surgery were collected and analyzed. Subgroup analyses determined a priori included timing of tracheostomy and type of procedure (open vs percutaneous). All analyses used the random effects model. A meta-regression analysis was performed on the proportion of sternal wound infection and number of days between tracheostomy and initial cardiac surgery.

Results: A total of 13 studies met inclusion criteria. The incidence of sternal wound infection across all studies reported was 7% (95% confidence interval [CI], 4-10). The percutaneous tracheostomy group had a sternal wound infection proportion of 3% (95% CI, 1-8), and the open tracheostomy group had a sternal wound infection proportion of 9% (95% CI, 5-14). The incidence of sternal wound infection with early (<14 days) (7%; 95% CI, 3-11) versus late (≥ 14 days) (7%; 95% CI, 4-10) tracheostomy was similar. Meta-regression demonstrated no significant relationship between incidence of sternal wound infection and number of days between tracheostomy and initial cardiac surgery ($R^2 = 6.13\%$, $P = .72$). Reported secondary outcomes included 30-day and 1-year mortality, which were high at 23% (95% CI, 19-28) and 63% (95% CI, 43-80), respectively.

Conclusions: The incidence of sternal wound infection after tracheostomy in patients undergoing cardiac surgery remains high at 7% (95% CI, 4-10). Open or percutaneous tracheostomy after cardiac surgery is a feasible option because the incidence of sternal wound infection and short-term mortality are comparable. Moreover, the timing of tracheostomy (early or late) had comparable rates of sternal wound infection and short-term mortality. (J Thorac Cardiovasc Surg 2017;153:1394-400)

Respiratory complications after cardiac surgery resulting in prolonged ventilation are common, particularly in high-risk subgroups.¹ Tracheostomy can be performed in

these patients to improve patient comfort and hasten ventilator weaning.^{2,3} Although respiratory insufficiency or prolonged intubation dominate as the main reasons for tracheostomy, heart failure and neurologic dysfunction are additional indications.⁴

Incidence of SWI after tracheostomy.

Central Message

The incidence of SWI after tracheostomy in patients undergoing cardiac surgery is 7%. Different techniques and timing of tracheostomy yielded comparable rates.

Perspective

SWI is a major complication that can occur after tracheostomy in patients undergoing cardiac surgery. Although the overall incidence of SWI is relatively high after tracheostomy, the timing of tracheostomy or type of tracheostomy technique did not demonstrate a large variation in SWI rates.

See Editorial Commentary page 1401.

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Abbreviations and Acronyms

CI = confidence interval
 POD = postoperative day
 SWI = sternal wound infection

Tracheostomy can be performed via the traditional open method or percutaneous method.^{5,6} This procedure has been implicated as a significant risk factor in sternal wound infections (SWIs) or mediastinitis,^{7,8} although other groups have not confirmed this correlation.^{9,10} Procedure-related factors that have been proposed as potential contributors to SWI include the timing and type of tracheostomy.^{11,12} In the cardiac surgical population, the incidence of SWI has not been studied as a primary outcome except in 1 small retrospective study.¹¹

Thus, the objective of this systematic review and meta-analysis was to report the incidence of SWI after tracheostomy in patients undergoing cardiac surgery and to determine whether the timing of tracheostomy (early vs late) or type of surgical technique (percutaneous vs open) resulted in a lower incidence of SWI.

MATERIALS AND METHODS

Eligibility Criteria

Randomized controlled trials, cohort studies, and observational studies published in English between November 15, 1985, and December 15, 2015, dealing with patients who underwent tracheostomy after any form of cardiac surgery were considered. Studies were included if they reported the primary outcome of interest (incidence of SWI). Secondary outcomes of interest included 30-day and 1-year mortality. Studies that included patients who had tracheostomy before cardiac surgery or included patients who had SWI before tracheostomy were excluded. Studies with sample sizes less than 50 were excluded to reduce the small-study effect bias.¹³ Although this systematic search included a timeframe between 1985 and 2015, all studies included in the final analysis were published after the year 2000.

Information Source, Search Strategy, and Data Extraction

The search strategy (Table E1) involved a detailed search of PubMed/MEDLINE, Embase, Cochrane Library, Clinical Trials Registry, relevant bibliographies, and Google Scholar. The methodology in this systematic review and meta-analysis conforms to PRISMA guidelines¹⁴ (Table E2, PRISMA checklist). There were a total of 562 articles identified on the initial search, which were then reviewed by 2 authors (HT and DF). After excluding articles on the basis of abstract information ($n = 332$) and duplicity ($n = 198$), 32 articles remained for full article review. Detailed reasons for exclusion of 19 articles are shown in Table E3. A total of 13 articles were included for the analysis (Figure E1).^{1,4,7-12,15-19} All 13 studies underwent primary data extraction by 2 authors (HT and DF). Any discrepancy between the data extracted from individual studies was resolved by the involvement of a third author. Qualitative assessment of each study was performed using the National Heart, Lung, and Blood Institute Quality of Assessment Tool for Observational Cohort or Controlled Intervention Studies (Table E4).²⁰

Data Items and Outcome Measures

The primary metaimeter of interest in this study was the incidence of SWI, which includes a composite outcome of superficial/deep SWI and mediastinitis incidence (based on the Society of Thoracic Surgeons definition).²¹ Secondary outcomes of interest included 30-day and 1-year mortality. Prespecified variables for subgroup analyses were extracted at the time of study review and placed into a standardized data-extraction form. These variables included type of tracheostomy (open vs percutaneous) and median postoperative days (PODs) between initial cardiac operation and tracheostomy. The latter variable was dichotomized to early (POD <14) versus late (POD ≥ 14) tracheostomy for subgroup analysis.

Statistical Methods

All analyses used the random effects model, and measures of heterogeneity were assessed using the Q statistic and I^2 . Subgroup random-effects meta-analysis models on predetermined variables were performed for type of tracheostomy procedure (open vs percutaneous) and timing of tracheostomy procedure (early vs late). Finally, a meta-regression was performed between the incidence of SWI and the timing of tracheostomy (median POD) after cardiac surgery using an unrestricted maximum likelihood model. Statistical analysis and figure generation were performed using STATA Version 12 (StataCorp LP, College Station, Tex).

RESULTS

A total of 10,088 patients were included from 13 studies. The study characteristics including first author, year of publication, type of tracheostomy, mean age, sex, type of reported SWI, and other medical history are presented in Table 1. The overall incidence of SWI after tracheostomy in patients undergoing cardiac surgery was 7.0% (95% confidence interval [CI], 4-10) (Figure 1). Significant heterogeneity was observed on the basis of a high Q statistic 440.5 ($P < .0001$) and I^2 of 94.1% (Figure 1). Subgroup analysis was performed by reporting the proportion of SWI based on type (Figure 2) and timing of tracheostomy (Figure 3). The proportion of SWI after percutaneous tracheostomy was 3% (95% CI, 1-8), whereas after open tracheostomy this was 9% (95% CI, 5-14) (Figure 2). Heterogeneity persisted in the open tracheostomy group ($I^2 = 94.0\%$, Q-stat = 151, $P < .0001$) but slightly decreased in the percutaneous group ($I^2 = 84.8$, Q-stat = 43, $P < .001$). The heterogeneity between subgroups was also different but not statistically significant (Q-stat = 2.2, $P = .063$). In addition, the incidence of SWI was almost identical in both time eras (year <2007: 7% [95% CI, 3-12] vs years 2007-2014; 7% [95% CI, 2-13]).

The proportion of SWI was 7% (95% CI, 3-11) in the early tracheostomy group and 7% (95% CI, 1-17) (Figure 3) in the late tracheostomy group. Heterogeneity persisted in both subgroups (early; $I^2 = 91.1\%$, late: $I^2 = 96.6$). Heterogeneity between these subgroups was not significant ($P = .896$). Meta-regression did not demonstrate a significant relationship between the timing of tracheostomy and the incidence of SWI, as depicted on the bubble plot ($R^2 = 6.13\%$, $P = .72$) (Figure 4). Because most studies reported 30-day mortality and to a lesser extent

TABLE 1. Summary of study-specific baseline characteristics

First author	Year	Country	Sample size (n)	Tracheostomy type	Age (y)*	Sex (% male)*	Median POD (d)	Type of SWI reported
Byhahn	2000	Germany	144	Percutaneous	—	53	9	Combination
Curtis	2001	USA	81	Open	68	70	18.7	Deep
Force	2005	USA	291	Open	68	77	15.7	Deep
Walts	2006	USA	188	Open	69	55	14	Superficial
Rahmanian	2007	USA	108	Open	72	53	12.5	Deep
Yavas†	2008	Turkey	71	Percutaneous	62	72	12.2	Deep
Yavas†	2008	Turkey	134	Open	61	69	11.5	Deep
Gaudino	2009	Italy	57	Open	67	52	5.6	Deep
Ballotta	2011	Italy	131	Percutaneous	—	57	11.7	Deep
Trouillet	2011	France	109	Percutaneous	64	71	5	Deep
Devarajan†	2012	USA	112	Open	72	61	8	Superficial
Devarajan†	2012	USA	329	Open	72	62	18	Superficial
Sun	2013	Canada	411	Open	69	63	14	Deep
Ben-Avi†	2014	Israel	90	Percutaneous	69	53	7	Deep
Ben-Avi†	2014	Israel	109	Percutaneous	71	51	18	Deep
Hosseinian	2014	USA	7723	Open	70	56	13	Deep

POD, Postoperative day; SWI, sternal wound infection; HTN, hypertension; COPD, chronic obstructive pulmonary disease; DM, diabetes; LVEF, left ventricular ejection fraction; CABG, coronary artery bypass grafting. *Represents mean value. †Duplicates indicate subgroup comparisons within each study by early versus late groups (Trouillet 2011; Devarajan 2012; Ben-Avi 2014) or open versus percutaneous groups (Yavas 2008).

1-year mortality, secondary metamer of interest was 30-day and 1-year mortality. The overall 30-day mortality rate was 23% (95% CI, 19-28). These values were comparable in the percutaneous group at 24% (95% CI, 10-41) and the open tracheostomy group at 23% (95% CI, 19-29) (Figure E2). Heterogeneity between these groups was not significant ($P = .992$). Moreover, 30-day mortality was comparable when groups were dichotomized to early versus late tracheostomy with 22% (95% CI, 16-30) and 25% (95% CI, 17-35) (Figure E3). Heterogeneity between these groups also was nonsignificant ($P = .589$).

The 1-year mortality rate was reported as 63% (95% CI, 43-80) and after subanalysis by type of tracheostomy performed, comparable mortality rates were observed with percutaneous at 67% (95% CI, 51-82) and open tracheostomy at 56% (95% CI, 16-92) (Figure E4). Because only 2 studies in the late tracheostomy group reported 1-year mortality, appropriate subanalysis based on timing of tracheostomy would not be constructive.

DISCUSSION

Tracheostomy is an invaluable procedure in the care of patients requiring prolonged ventilation after cardiac surgery; however, the impact of this intervention on SWI is not known. In this study, the incidence of SWI as a composite of superficial/deep SWI and mediastinitis after tracheostomy after cardiac surgery was determined to be 7% (95% CI, 4-10). To determine whether the type or timing of tracheostomy was a potential source of heterogeneity, a priori subgroup analyses were performed. Although this study did not statistically compare the incidence of SWI by

tracheostomy procedure, the percutaneous tracheostomy group had a 3% (95% CI, 1-8) incidence of SWI, whereas the open tracheostomy group had a 9% (95% CI, 5-14) incidence of SWI. In addition to newer techniques, antibiotics, and prepping solutions in the percutaneous group, another potential reason for an observed lower incidence of SWI in the percutaneous group may be explained by the less-invasive nature of the operation.²² Heterogeneity also was borderline significant between the percutaneous and open tracheostomy groups ($I^2 = 94.1\%$; $P = .063$). This may be explained by the inherent selection bias: Patients receiving a percutaneous tracheostomy may be more hemodynamically stable or less obese. Compared with the open tracheostomy group, the percutaneous group had less within-group heterogeneity, further implying some degree of selection bias. Therefore, this could explain the observed lower proportion of SWI in the percutaneous group. Because the studies spanned a 15-year period, we also performed a subanalysis dichotomized to early years of study (<2007) to more recent years of study (2007-2014). The incidence of SWI was almost identical in both eras (<2007: 7% [95% CI, 3-12] vs 2007-2014; 7% [95% CI, 2-13]), implying that study era may not influence the incidence of SWI.

The timing of tracheostomy, dichotomized to early or late, demonstrated similar incidences of SWI. Heterogeneity in either subgroup persisted compared with the overall analysis. Last, a meta-regression analysis was performed and determined that no significant linear relationship existed between the incidence of SWI and median POD for tracheostomy. This finding is further corroborated by the exact same incidence of SWI after subgroup analysis in

TABLE 1. Continued

HTN (%)*	COPD (%)*	DM (%)*	Renal failure (%)*	LVEF (%)*	Redo (%)*	CABG (%)*	Valve surgery (%)*	30-d mortality (%)*	1-y mortality (%)*
50	11	26	—	—	29	65.3	9.7	—	—
—	28.4	40	—	—	8.1	—	—	24.7	—
—	20	36	19	45	—	65	—	—	22.7
—	22	24	4	—	38	59	33	25	—
78	18.5	32	10.2	—	25.9	20.4	31.5	11.1	—
—	50.7	39	25.4	—	43.7	—	—	—	84.5
—	49.3	46	32.1	—	47.8	—	—	—	81.3
25.9	55.4	32	—	—	25.9	31.6	54.4	19.2	63.1
8.2	15.3	16	—	45	11	32	—	49	71
—	11	24	16	—	—	25	—	16	35.8
75.4	24.4	39	—	—	40.5	70.7	—	22	—
71.9	18.3	41	—	—	40.5	60.4	—	36.1	—
—	19.5	34	—	—	16.8	—	—	—	—
64	17	29	4	46	34	16	20	17.8	55.6
59	15	45	6	45	29	26	24	15.6	74.3
—	25	—	24.5	—	—	49.5	—	24.6	—

early versus late tracheostomy groups. The incidence of SWI in tracheostomy cases after cardiac surgery is larger than the general cardiac surgical population, which has

been reported to range from 0.7% to 3.2%.²³⁻²⁵ The increased incidence of SWI may be partially explained by several other risk factors present in postoperative

FIGURE 1. Forest plot with proportion of SWI after tracheostomy across all studies. Duplicate studies represent early versus late groups of patients. ES, Effect size/incidence; CI, confidence interval.

FIGURE 2. Subgroup analysis of the proportion of SWI after percutaneous (A) or open (B) tracheostomy. ES, Effect size/incidence; CI, confidence interval.

tracheostomy cases. For example, in this meta-analysis of more than 10,000 patients, there was a high incidence of diabetic patients, elderly patients, patients with chronic obstructive lung disease, and patients undergoing reoperative surgery.¹⁰ This potentially supports the belief that tracheostomy may not be a risk factor for developing SWI but merely acts as an overall indicator of patient critical illness. Significant heterogeneity was observed in the meta-analysis for overall incidence of SWI with an $I^2 = 94.1\%$. This may be partially explained by the variability in reporting superficial or deep SWIs (several modifications for diagnostic criteria have been made over the last decade) and the lack of controlled study designs (11/13 studies were retrospective).

The secondary metameter of interest included 30-day and 1-year mortality, which were high at 23% (95% CI, 19-28) and 63% (95% CI, 43-80), respectively. Furthermore, after stratifying by type of tracheostomy procedure, the 30-day and 1-year mortality rates were identical. This implies that percutaneous or open tracheostomy is a safe option for patients undergoing cardiac surgery with respiratory

failure. Likewise, the timing of tracheostomy (early vs late) did not change the 30-day mortality, implicating that either timing option is feasible. Despite no major differences in mortality between type and timing of tracheostomy, the absolute 30-day and 1-year mortality rates were high at 23% and 63%, respectively. These elevated mortality rates are likely a surrogate marker of significant disease burden and poor long-term outcomes as opposed to the tracheostomy procedure itself, a procedure typically with a low perioperative mortality (<1%).²⁶

Study Limitations

The large amount of heterogeneity is a limitation of the current study. Attempts to identify potential sources of heterogeneity with subgroup analyses failed to fully explain this finding. As discussed previously, major sources of heterogeneity may include the varying diagnostic criteria for SWI, a wide range of cardiac surgical procedures (multivalve, bypass, type of grafts including bilateral vs single internal thoracic artery), patient comorbidities, and

FIGURE 3. Subgroup analysis of the proportion of SWI found in early (A) tracheostomy versus late (B) tracheostomy. ES, Effect size/incidence; CI, confidence interval.

small datasets, most of which are retrospective in nature. In addition to varying diagnostic criteria for SWI, some studies reported only superficial^{2,17} or a combination of superficial/deep SWI¹⁵ ($n = 3$), whereas the remaining

studies reported deep-seated SWI or mediastinitis (10/13). When the studies reporting superficial SWI were removed, the overall effect estimate and the degree of heterogeneity did not change. Although this meta-analysis collected only a handful of studies ($n = 13$), publication bias seemed to be minimal according to the Egger's test ($P = .15$); however, the Begg's test ($P = .053$) used for assessment of publication bias demonstrates that there is likely some degree of publication bias due to the equivocal P value. Despite these limitations, this is the only study that has systematically reported the incidence of SWI after tracheostomy in patients undergoing cardiac surgery and looked at whether the type or the timing of tracheostomy played a role in the development of SWI.

CONCLUSIONS

The incidence of SWI followed by tracheostomy in patients undergoing cardiac surgery remains high at 7%. Open or percutaneous tracheostomy after cardiac surgery is a feasible option because SWI incidence and short-term mortality are comparable. Furthermore, although the timing

FIGURE 4. Meta-regression (bubble blot) comparing the incidence of SWI with the median POD from tracheostomy to initial cardiac surgery. SWI, Sternal wound infection; POD, postoperative day.

of tracheostomy (early vs late) may improve patient comfort and weaning from ventilation as described previously,¹² this meta-analysis demonstrated comparable proportions of SWI and short-term mortality. Further studies are needed to determine which strategy (open vs percutaneous; early vs late) generates faster patient recovery and lowers overall cost.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: cardiac surgery, sternal wound infection, tracheostomy

FIGURE E1. Flow diagram.

FIGURE E2. Forest plot subgroup analysis of the 30-day mortality after percutaneous (A) or open (B) tracheostomy. *ES*, Effect size/incidence; *CI*, confidence interval.

FIGURE E3. Forest plot subgroup analysis of the 30-day mortality after early (A) or late (B) tracheostomy. *ES*, Effect size/incidence; *CI*, confidence interval.

FIGURE E4. Forest plot subgroup analysis of the 1-year mortality after percutaneous (A) or open (B) tracheostomy. *ES*, Effect size/incidence; *CI*, confidence interval.

TABLE E1. Search methodology

Database	Specific search strategy	Keywords searched
PubMed/MEDLINE	1 = thoracic surgery/ 2 = exp Cardiac Surgical Procedures/ 3 = Cardiopulmonary Bypass/ 4 = ((cardiac or heart) adj2 (surg* or operation* or bypass or transplant*)).tw. 5 = (coronary artery adj2 (bypass or surg* or graft*)).tw. 6 = cabg.tw. 7 = ((cardiac or mitral) adj2 (annuloplasty or surg*)).tw. 8 = or/1-7 9 = exp heart diseases/ 10 = su.fs. 11 = 9 and 10 12 = 8 or 11 13 = tracheostom*.hw,tw. 14 = 12 and 13	Cardiac Surgery*, Thoracic Surgery*, Tracheostomy*
EMBASE	1 = thoracic surgery/ 2 = Cardiopulmonary Bypass/ 3 = ((cardiac or heart) adj2 (surg* or operation* or bypass or transplant*)).tw. 4 = (coronary artery adj2 (bypass or surg* or graft*)).tw. 5 = cabg.tw. 6 = ((cardiac or mitral) adj2 (annuloplasty or surg*)).tw. 7 = or/1-6 8 = tracheostom*.hw,tw. 9 = 7 and 8	Cardiac Surgery*, Thoracic Surgery*, Tracheostomy*
Google Scholar	Not applicable	Cardiac Surgery or Thoracic Surgery or coronary artery bypass surgery, Tracheostomy*
Clinical Trials Registry	Not applicable	Cardiac Surgery*, Thoracic Surgery*, Tracheostomy*
Cochrane Library	Not applicable	Cardiac Surgery*, Thoracic Surgery*, Tracheostomy*

TABLE E2. PRISMA checklist

Section/topic	No.	Checklist item	Reported on page no.
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.	3
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 PICOS.	5
Methods			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (eg, Web address), and, if available, provide registration information including registration number.	6
Eligibility criteria	6	Specify study characteristics (eg, PICOS, length of follow-up) and report characteristics (eg, years considered, language, publication status) used as criteria for eligibility, giving rationale.	6
Information sources	7	Describe all information sources (eg, databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6
Search	8	Present full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	6
Study selection	9	State the process for selecting studies (ie, screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (eg, piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought (eg, PICOS, funding sources) and any assumptions and simplifications made.	6
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.	6
Summary measures	13	State the principal summary measures (eg, risk ratio, difference in means).	6-7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (eg, I^2) for each meta-analysis.	6-7
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (eg, publication bias, selective reporting within studies).	12
Additional analyses	16	Describe methods of additional analyses (eg, sensitivity or subgroup analyses, meta-regression), if done, indicating which were prespecified.	7-8
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.	Figure E1, Table E4
Study characteristics	18	For each study, present characteristics for which data were extracted (eg, study size, PICOS, follow-up period) and provide the citations.	Table E1
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).	Table E3
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 CIs, ideally with a forest plot.	Figure 1

(Continued)

TABLE E2. Continued

Section/topic	No.	Checklist item	Reported on page no.
Synthesis of results	21	Present results of each meta-analysis done, including CIs and measures of consistency.	Figures 1-4
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	12
Additional analysis	23	Give results of additional analyses, if done (eg, sensitivity or subgroup analyses, meta-regression [see Item 16]).	Figure 4, Figures E2-E4
Discussion			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (eg, healthcare providers, users, and policy makers).	13
Limitations	25	Discuss limitations at study and outcome level (eg, risk of bias), and at review level (eg, incomplete retrieval of identified research, reporting bias).	12
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	13
Funding			
Funding	27	Describe sources of funding for the systematic review and other support (eg, supply of data); role of funders for the systematic review.	15

PICOS, Participants, interventions, comparisons, outcomes, and study design; CI, confidence interval. From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. *PLoS Med.* 2009;6:e1000097.

TABLE E3. Quality assessment tool for observational cohort or randomized controlled intervention studies

Author	Year	Quality rating
Byhahn	2000	Poor
Curtis	2001	Poor
Force	2005	Fair
Walts	2006	Poor
Rahmanian	2007	Fair
Yavas	2008	Fair
Gaudino	2009	Fair
Ballotta	2011	Good
Trouillet	2011	Good
Devarajan	2012	Good
Sun	2013	Good
Ben-Avi	2014	Fair
Hosseinian	2014	Fair

TABLE E4. Reasons for study exclusion

Author, y	Reason for exclusion
Balasubramaniam MS, 2010	Abstract/conference
Bryan CS, 2013	Review
Dimarakis I, 2010	Abstract/conference
Gelape CL, 2007	Review
Gulmen S, 2009	Abstract/conference
Kubota H, 2013	Review
Kusachi S, 2009	Abstract/conference
Lehr EJ, 2011	Case report
Marulli G, 2012	Abstract/conference
Mitrev Z, 2011	Abstract/conference
Okonta KE, 2011	Review
Pilarczyk K, 2014	Abstract/conference
Reyna GC, 2006	Review
Sachithanandan A, 2008	Tracheostomy-specific outcomes not reported
Singh K, 2011	Review
Stamenkovic SA, 2000	SWI outcome not reported
Vollroth M, 2011	Abstract/conference
Wasowicz M, 2009	Abstract/conference
Wagner F, 1998	SWI outcome not reported

SWI, Sternal wound infection.