

Percutaneous or surgical tracheostomy: A meta-analysis

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Objective: To compare percutaneous with surgical tracheostomy using a meta-analysis of studies published from 1960 to 1996.

Data Sources: Publications obtained through a MEDLINE database search with a Boolean combination (*tracheostomy* or *tracheotomy*) and *complications*, with constraints for human studies and English language.

Study Selection: Publications addressing all peri- and postoperative complications. Studies limited to specific tracheostomy complications or containing insufficient details were excluded. Two authors independently selected the publications.

Data Extraction: A list of relevant surgical variables and complications was compiled. Complications were divided into peri- and postoperative groups and further subclassified into severe, intermediate, and minor groups. Because most studies of percutaneous tracheostomy were published after 1985, surgical tracheostomy studies were divided into two periods: 1960 to 1984 and 1985 to 1996. The articles were analyzed independently by three investigators, and rare discrepancies were resolved through discussion and data reexamination.

Data Synthesis: Earlier surgical tracheostomy studies (n = 17;

patients, 4185) have the highest rates of both peri- (8.5%) and postoperative (33%) complications. Comparison of recent surgical (n = 21; patients, 3512) and percutaneous (n = 27; patients, 1817) tracheostomy trials shows that perioperative complications are more frequent with the percutaneous technique (10% vs. 3%), whereas postoperative complications occur more often with surgical tracheostomy (10% vs. 7%). The bulk of the differences is in minor complications, except perioperative death (0.44% vs. 0.03%) and serious cardiorespiratory events (0.33% vs. 0.06%), which were higher with the percutaneous technique. Heterogeneity analysis of complication rates shows higher heterogeneity in older and surgical trials.

Conclusions: Percutaneous tracheostomy is associated with a higher prevalence of perioperative complications and, especially, perioperative deaths and cardiorespiratory arrests. Postoperative complication rates are higher with surgical tracheostomy. (Crit Care Med 1999; 27:1617-1625)

KEY WORDS: tracheostomy; tracheotomy; percutaneous; surgery; complications; meta-analysis; mortality; review; endoscopy; devices

Tracheostomy was probably performed in ancient Egypt, and the first elective tracheostomy is attributed to Asclepiades of Bithynia around 100 BC (1, 2). In the 19th century, tracheostomy became an established procedure for upper airway obstruction secondary to a foreign body, trauma, and infections, such as diphtheria and croup. Tracheostomy was viewed as a very dangerous operation until Chevalier Jackson (3) defined the surgical principles of the procedure, which are still in use today. Jackson (3) emphasized a long incision, good exposure, division of the thyroid isthmus, and in a later pub-

lication, avoidance of incision of the first and second tracheal rings (4).

Although the operation became codified, the development of endotracheal intubation (5, 6) greatly facilitated the procedure by removing its emergency status in numerous cases. Also, control of diphtheria by immunization and the availability of antibiotics for the treatment of upper airway infections made tracheostomy an elective procedure for most patients. The indications of the procedure extended beyond upper airway obstruction to encompass treatment of chronic obstructive pulmonary disease after the realization that tracheostomy reduces pulmonary dead space (7), provides access for clearing of abundant pulmonary secretions in numerous pathologies (7, 8), and improves the patient's comfort during weaning from the respirator. Probably the most dramatic medical advance attributable to tracheostomy was in the management of poliomyelitis-induced respiratory paralysis by using tracheostomy to deliver positive pressure ventilation (9).

In the 1960s, the indications for tracheostomy were clarified (10, 11), and

sterile suction and cannula changes were introduced (10, 12). Cuffed tracheostomy tubes appeared (13), which presented new problems such as tracheal stenosis (14), obstruction of the tube lumen by prolapsed cuffs, and even extrusion of the tracheostomy tube, sometimes resulting in fatalities (10, 11). Although the introduction of low-pressure cuffs for tracheostomy tubes certainly helped in reducing these complications, these cuffs were also used for endotracheal tubes, allowing for prolonged intubation, and a new controversy began on the duration of prolonged endotracheal intubation. The appropriate timing of tracheostomy in intubated patients is yet to be defined (15).

Several publications have described a prohibitively high rate of complications with surgical tracheostomy (SgT) (10, 11, 16-18). Several devices are, therefore, proposed to create a puncture in the pretracheal skin and soft tissues to allow access to the tracheal lumen (19-23). This procedure is called percutaneous tracheostomy (PcT) (19) and is proposed as a new bedside procedure with lower morbidity (20). However, articles show-

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ing PcT complication rates higher than those for SgT have been published (23–28).

To critically evaluate the pros and cons of PcT, we reviewed the complication rates of tracheostomy, both surgical and percutaneous. Because the majority of literature on PcT appears after 1985, the review of SgT complications was subdivided into two periods: 1960 to 1984 (SgT_{1960–1984}) and 1985 to 1996 (SgT_{1985–1996}). This allowed comparison between the two procedures during the same period of medical care, with the hope of decreasing the role of other variables, such as intensive care equipment, monitoring, reanimation techniques and drugs, and posttracheostomy nursing protocols. In addition, the use of low-pressure cuffs has been standard for the last 15 yrs.

MATERIALS AND METHODS

Literature Search and Article Selection. The MEDLINE database was searched from 1960 to 1996 with a Boolean combination: (tracheotomy or tracheostomy) and complications. Only human studies published in English were included. To locate recent publications not yet indexed in MEDLINE, the Current Content issues for the last 3 months of 1996 were reviewed. The search was supplemented by cross-checking the references in each article. The search was conducted independently by two investigators.

As previously stated, the publications on SgT complications were separated in two periods, 1960 to 1984 (SgT_{1960–1984}) and 1985 to 1996 (SgT_{1985–1996}). Three articles published in the early 1960s (10, 11, 29) clearly stated that the procedures were performed before 1960 and were, therefore, excluded. Also, two articles on PcT, published before 1985 (19, 23) and concerning nine patients, were excluded. We excluded publications with fewer than five patients (28, 30), because these were more likely to be selected case reports of adverse effects rather than studies of representative samples.

Review articles and publications limited to specific tracheostomy complications, such as tracheal stenosis and tracheoinnominate fistula, were excluded. To be included, publications had to address complications of tracheostomy during the procedure, in the early postoperative period, and delayed or long-term complications. Several articles were excluded because of insufficient data about the complications encountered (31–46).

Several publications stress that emergency tracheostomy (43, 47) and tracheostomy in pediatric patients (16, 48) are associated with a much higher rate of complications than elective procedures in adult patients. PcT is an elective procedure performed in intubated adult patients (20, 21, 23–27, 49–69). A single article on pediatric percutaneous tracheos-

tomy by Toursarkissian et al. (70), concerning 11 patients with a mean age of 16 yrs, was excluded.

Ideally, the complications of PcT should be compared with SgT series in which all patients are adults operated on an elective basis. Although most SgT publications in the more recent 1985 to 1996 period (26, 56, 57, 60, 64, 65, 68, 71–84) fulfill these criteria, only two SgT_{1960–1984} articles (17, 85) clearly excluded children and emergent procedures. Because excluding all remaining publications on SgT in the 1960 to 1984 period (18, 47, 86–98) would have made the results difficult to compare with complication rates and articles usually cited in the literature, these publications were included, despite the possibility of a bias. The selection of publications was performed independently by two investigators (PD and CG).

Data Extraction. A list of the complications of tracheostomy was compiled from recent reviews (99, 100) and supplemented with the complications listed in the selected articles. A somewhat arbitrary separation was made between perioperative complications, which include complications during the procedure and those occurring in the next 24 to 48 hrs, and postoperative complications covering the remaining time interval, whatever it was in the given publication. Ideally, patients should have been followed up either until their death or until the trachea had been allowed to heal for several months after ablation of the tracheostomy tube. Such an extensive duration was studied in some, but not all, publications.

Both perioperative and postoperative complications were further subdivided into serious, intermediate, and minor groupings. Serious complications are, for the most part, objectively defined and are probably difficult to miss (death, cardiopulmonary arrest, pneumothorax, pneumomediastinum, tracheoesophageal fistula, mediastinitis, sepsis, intratracheal postoperative hemorrhage, cannula obstruction and displacement, and tracheal stenosis). Although the definition of most complications classified as intermediate is precise and objective, the complications could have been missed in chart review studies. Intermediate complications, when recognized and treated appropriately, should not result in serious morbidity. Complications classified as intermediate include intraoperative desaturation, lesions of the posterior tracheal wall, cannula misplacement, switch of a PcT procedure to a surgical technique, aspiration, pneumonia, atelectasis, and lesions of the tracheal cartilages. Finally, minor complications are somewhat subjective, less serious, easier to correct, and rely on the diligence with which they are sought and reported (intraoperative hemorrhage, tube false passage, difficulty with tube placement, subcutaneous emphysema, postoperative wound hemorrhage, infections such as wound cellulitis and tracheitis, and late problems such as delayed closure of tracheostomy tract, keloids, and unaesthetic

scarring). Rarely described complications were not considered, unless they resulted in serious or fatal events.

Once the complication list was established, the selected publications were analyzed independently by three investigators (PD, CG, and J-CC) and the complications were tabulated. Discordant results were discussed, and the publications were rechecked to achieve an agreement.

Data Analysis. The frequency of each of the 32 complications was summed across publications for each study group (SgT_{1960–1984}, SgT_{1985–1996}, and PcT), divided by the total number of patients in each study group, and expressed as events per 10,000 procedures. Complication rates per study group were compared using the Fisher's exact test (two-sided). Two independent comparisons were performed: SgT_{1960–1984} vs. SgT_{1985–1996} and SgT_{1985–1996} vs. PcT. We considered *p* values of <.05 to be statistically significant. Those readers who wish to take the number of tests (62, since "switch to surgical technique" is, by definition, a complication solely of PcT) into account should consider as significant only *p* values of <.00083, the wisdom of Bonferroni adjustments (101) being a matter of current debate (102, 103). In addition, Bonferroni adjustments assume that all tests are mutually independent. This might not be the case for postoperative complications, which are often related and tend to occur in the same patients. In this situation, the use of Bonferroni adjustments would be too conservative.

To summarize findings, we also computed totals of complications in each of six subgroups (serious, intermediate, and minor, both peri- and postoperative). For each category of complications (serious, intermediate, and minor), subtotals were calculated for each publication and a weighted average was obtained by taking into account the number of patients in each publication (subjects at risk). The number of perioperative, postoperative, and total complications per publication were obtained by summing the subtotals for each category of complications. Differences between tracheostomy groups regarding these summary variables were tested in models that used the total complications that could occur: number of patients times the number of possible complications. However, these tests are correct only if, in a given patient, events (complications) are mutually independent. If complications were clustered in the same patients, the *p* values derived from this analysis would be too extreme, i.e., biased toward rejection of the null hypothesis. Unfortunately, no data on the independence of complications were available in the majority of reviewed publications.

Our analysis was based on the premise that published studies provide a systematic and representative picture of the general practice of surgical and percutaneous tracheostomy. Ideally, all studies would include similar populations of patients, the procedures performed using the same technique, the complications

Table 1. Characteristics of the studies included in the tracheostomy groups

	SgT ₁₉₆₀₋₁₉₈₄	SgT ₁₉₈₅₋₁₉₉₆	PcT
No. of studies	17	21	27
References	17, 18, 47, 85-98	26, 56, 57, 60, 64, 65, 68, 71-84	20, 21, 24-27, 49-69
No. of patients	4185	3512	1817
Mean age	51.2 ± 11.5	64.5 ± 7.8	44.8 ± 6.9
Pediatric cases (%)	6.5 ± 6.6	0.0	0.06 ± 0.2
Emergency cases (%)	31.5 ± 24	5.6 ± 7	1.4 ± 4.7
Days of intubation	4.0 ± 3.6	12.7 ± 5.2	13.1 ± 3.9
Duration of procedure (mins)	NA	26.9 ± 16.5	11.7 ± 6.5
Location: % in ICU	15.5 ± 24	65.9 ± 46	84.3 ± 27.6

SgT, surgical tracheostomy; PcT, percutaneous tracheostomy; ICU, intensive care unit; NA, not applicable.

The averages and standard deviations for the pediatric cases, emergency cases, days of intubation, duration, and location of the procedure are not based on the entire population for each group, because certain studies did not give all the variables (see text for details).

recorded using the same standard protocol, and that the authors published all available information. If this were true, we would expect studies in a given subgroup to provide similar results, with differences being attributable only to chance. Results would be homogeneous, and statistical tests of heterogeneity should be nonsignificant 95% of the time. On the contrary, if studies varied in their patient populations, technical procedures, recording of complications, and reporting, we would expect heterogeneity between studies in the same subgroup. This is clearly a more realistic scenario. The problem with heterogeneity is that averaging across heterogeneous studies yields results that are difficult to interpret.

To examine the heterogeneity between studies within each group (PcT, SgT₁₉₆₀₋₁₉₈₅, SgT₁₉₈₅₋₁₉₉₆), we compared study-specific complication rates using a Fisher's exact test. Because of the large number of studies involved, we used an approximation of the Fisher's exact test based on 10,000 Monte Carlo simulations, as implemented in SPSS 6.0 (SPSS, Inc., Chicago, IL). Because 94 heterogeneity tests were performed, the Bonferroni-adjusted *p* value would be .00053.

To examine temporal changes in death rates, we plotted death rates against study publication years and examined trends, separately for SgT and PcT, by means of nonparametric regression lines (104), which allow for a comparison between two variables without imposing a specific (linear) relationship.

Subsets Analysis. Because it has been argued that PcT complications could be influenced by the particular PcT "set" used (24, 60), a subset analysis was performed on PcT studies. The selected PcT publications were subdivided in three groups: those using the progressive dilation technique (20), those using the same progressive dilation technique and performing the procedure under endoscopic control (30), and those using other tracheostomy "sets." Similar data grouping and statistical tests were used.

RESULTS

Seventeen articles published between 1960 and 1984 and analyzing tracheostomy complications in 4188 patients constitute the SgT₁₉₆₀₋₁₉₈₄ group (Table 1). In this group, the number of pediatric tracheostomies was specified in eight studies (17, 47, 85-90) with an average rate of pediatric cases of 6.5%. The percentage of emergency tracheostomies was specified in 12 publications (17, 18, 47, 85, 87-94), for an average of 31.5%. Only four studies indicated the number of intubation days (17, 18, 85, 87) and the location of the procedure (18, 85, 89, 90), with average numbers of 4 days and 15% intensive care unit (ICU) tracheostomies. No publication in this group indicated the duration of the procedure (Table 1).

Twenty-one publications concerning 3512 patients who underwent SgT between 1985 and 1996 constitute the SgT₁₉₈₅₋₁₉₉₆ group (Table 1). Sixteen of these studies (26, 56, 57, 60, 64, 65, 68, 71, 73-78, 82, 84) clearly stated that no pediatric cases were included. The number of emergency tracheostomies was specified in 18 studies (26, 56, 57, 60, 64, 65, 68, 71-74, 76, 77, 80-84) and averaged 5.6%. The number of intubation days was indicated in nine articles (26, 57, 65, 68, 71, 72, 76, 81, 82), with an average of 12.7 days. The duration of the procedure was specified in six publications (56, 57, 60, 64, 68, 83) and averaged 26.9 mins. The location of the surgery was indicated in 17 articles (26, 60, 64, 65, 68, 71-75, 77-80, 82-84), and the procedure was performed in the ICU in 66% of cases (Table 1).

Twenty-seven articles were published between 1985 and 1996 on percutaneous tracheostomies (PcT) in 1817 patients (Table 1). The majority (26) of publications did not contain pediatric cases. Only one article (49) indicated a pediatric PcT in one patient for an overall rate of 0.06%. The number of emergency tracheostomies was indicated in 24 articles (20, 21, 24-27, 49-51, 54-57, 59-69), for an average of 1.44%. The number of intubation days before tracheostomy was specified in 12 articles (21, 25, 26, 50, 51, 53, 55, 57, 65, 66, 68, 69) and the average was 13.1 days. The duration of the PcT was indicated in 12 publications (21, 24, 53, 56, 57, 59, 60, 62, 64, 66, 68, 69), for an average of 11.7 mins. In 19 publications (21, 24-26, 50, 53-57, 59, 60, 62-66, 68, 69), the average number of ICU PcT was 84% (Table 1).

Perioperative Complications (Table 2)

Serious perioperative complications, i.e., perioperative death, cardiorespiratory arrest, pneumothorax, or pneumomediastinum, were noted in 239 per 10,000 SgT₁₉₆₀₋₁₉₈₄, in 86 per 10,000 SgT₁₉₈₅₋₁₉₉₆, and in 149 per 10,000 PcT. These differences are statistically significant.

The perioperative death rates were ten times higher for SgT₁₉₆₀₋₁₉₈₄ and PcT compared with SgT₁₉₈₅₋₁₉₉₆ data (*p* = .001). Similarly, cardiorespiratory arrest rates were the highest for the SgT₁₉₆₀₋₁₉₈₄ group, followed by the PcT group, and the lowest for the SgT₁₉₈₅₋₁₉₉₆ group. The death rates are also displayed graphically in Figure 1, *top left*. Perioperative pneumothorax was more frequent in the older SgT group, with a similar frequency in the SgT₁₉₈₅₋₁₉₉₆ and the PcT groups. In fact, perioperative pneumothorax accounted for approximately one-half of the serious complications in the SgT₁₉₆₀₋₁₉₈₄ group and for close to the total of the SgT₁₉₈₅₋₁₉₉₆ group.

Intermediate perioperative tracheostomy complications, i.e., desaturation or hypotension, lesions of the posterior tracheal wall, misplacement of the tracheostomy cannula, aspiration during the surgery, and switching to the surgical technique, were noted in 84 per 10,000 SgT₁₉₆₀₋₁₉₈₄, in 46 per 10,000 SgT₁₉₈₅₋₁₉₉₆, and in 254 per 10,000 PcT (*p* < .05). Desaturation and hypotension did not appear in the SgT₁₉₆₀₋₁₉₈₄ publications, probably because of underre-

Table 2. Perioperative complications classified as serious, intermediate, and minor in the three tracheostomy groups

Perioperative Complications	SgT ₁₉₆₀₋₁₉₈₄	SgT ₁₉₆₀₋₁₉₈₄ vs. SgT ₁₉₈₅₋₁₉₉₆	SgT ₁₉₈₅₋₁₉₉₆	SgT ₁₉₈₅₋₁₉₉₆ vs. PcT	PcT
Serious (total)	239	<0.00001 ^a	86	0.049 ^a	149
Death	38	0.00082	3	0.00114	44
Cardiopulmonary arrest	60	0.00002	6	0.02203	33
Pneumothorax	110	0.122	74	1.0	66
Pneumomediastinum	31	0.00497	3	0.864	6
Intermediate (total)	84	0.048 ^a	46	<0.00001 ^a	254
Desaturation/hypotension	0	0.00264	23	0.00560	77
Posterior tracheal wall lesion	5	1.0	6	0.00163	50
Cannula misplacement	55	0.00796	17	0.089	44
Switch to surgical technique	—	—	—	—	83
Aspiration	24	0.00264	0	—	0
Minor (total)	531	<0.00001 ^a	179	<0.00001 ^a	628
Hemorrhage	170	0.359	142	1.0	143
Difficult tube placement	0	0.208	6	0.00001	220
False passage	12	1.0	11	0.00001	160
Subcutaneous emphysema	349	0.00001	20	0.00007	105
Total perioperative complications	854	<0.00001 ^a	311	<0.00001 ^a	1031

SgT, surgical tracheostomy; PcT, percutaneous tracheostomy.

Results are expressed as events per 10,000 procedures.

^a*p* Values were computed assuming an independence between complications within each category. If this hypothesis were incorrect, *p* values would be biased toward rejection of the null hypothesis.

porting. These complications appear to be more frequent in PcT studies, similarly to lesions of the posterior tracheal wall. Cannula misplacement was the least frequent with SgT₁₉₈₅₋₁₉₉₆. A switch to the surgical technique is, by definition, a complication of PcT and occurred in <1% of PcT cases. Perioperative aspiration was not noted in recent studies of both PcT and SgT₁₉₈₅₋₁₉₉₆ groups.

Minor perioperative tracheostomy complications, i.e., hemorrhage, difficulty in tracheostomy tube placement, false passage during the introduction of the tube, and subcutaneous emphysema, were noted in 531 per 10,000 SgT₁₉₆₀₋₁₉₈₄, in 179 per 10,000 SgT₁₉₈₅₋₁₉₉₆, and in 628 per 10,000 PcT (*p* < .001). Hemorrhage was present evenly in each study group. Difficulty in the introduction of the tracheostomy tube, either noted per se or described as a false passage, was clearly more frequent with PcT (*p* < .001). Subcutaneous emphysema appeared to be the least frequent in SgT₁₉₈₅₋₁₉₉₆ publications, with a higher frequency in PcT studies, and the highest occurrence in the SgT₁₉₆₀₋₁₉₈₄ articles, in which it accounted for two-thirds of all minor perioperative complications.

Postoperative Complications (Table 3)

Serious postoperative complications, i.e., postoperative death attributable to the tracheostomy procedure, tracheoesophageal fistula, mediastinitis or sepsis second-

ary to the tracheostomy, pneumothorax, postoperative cannula obstruction or displacement, and tracheal stenosis were noted in 845 per 10,000 SgT₁₉₆₀₋₁₉₈₄, in 256 per 10,000 SgT₁₉₈₅₋₁₉₉₆, and in 278 per 10,000 PcT. Postoperative mortality rates are ten times higher for SgT₁₉₆₀₋₁₉₈₄ relative to both SgT₁₉₈₅₋₁₉₉₆ and PcT data (*p* < .001). The postoperative mortality rates are also displayed graphically in Figure 1, *top right*.

For the majority of serious postoperative complications, the highest rates are found in the SgT₁₉₆₀₋₁₉₈₄ publications. For most serious postoperative complications, the difference between SgT₁₉₆₀₋₁₉₈₄ and SgT₁₉₈₅₋₁₉₉₆ rates were statistically significant. The rates of serious postoperative complications were roughly similar for SgT₁₉₈₅₋₁₉₉₆ and PcT data. The only complications significantly different between SgT₁₉₈₅₋₁₉₉₆ and PcT data were intratracheal hemorrhage, which was more frequent in SgT₁₉₈₅₋₁₉₉₆, and postoperative pneumothorax and tracheal stenosis, which were found more often with PcT.

Intermediate postoperative tracheostomy complications, i.e., pneumonia, atelectasis, aspiration, and lesions of tracheal cartilages (tracheomalacia, tracheal granuloma) were noted in 1063 per 10,000 SgT₁₉₆₀₋₁₉₈₄, in 146 per 10,000 SgT₁₉₈₅₋₁₉₉₆, and in 78 per 10,000 PcT. For each complication, the highest rates were found in the SgT₁₉₆₀₋₁₉₈₄ group,

with statistically significant differences between the SgT₁₉₆₀₋₁₉₈₄ and SgT₁₉₈₅₋₁₉₉₆ groups in all cases. For unclear reasons, pneumonia was absent in PcT data, and tracheal cartilage lesions were infrequent in SgT₁₉₈₅₋₁₉₉₆ data.

Minor postoperative complications, i.e., external hemorrhage, wound infection, tracheitis, delayed closure of the tracheostomy wound after cannula ablation, keloids, and unaesthetic scars, were noted in 1372 per 10,000 of SgT₁₉₆₀₋₁₉₈₄, in 561 per 10,000 SgT₁₉₈₅₋₁₉₉₆, and in 342 per 10,000 PcT (*p* < .001). The occurrence of postoperative wound hemorrhage was similar in the three groups. Wound infection and tracheitis were more frequent with SgT techniques. Although the differences were not as important, delayed cutaneous closure, keloids, and unaesthetic scars were also found more often in SgT₁₉₆₀₋₁₉₈₄ data, with a much lower frequency in SgT₁₉₈₅₋₁₉₉₆ and PcT studies. The subtotals for serious, intermediate, and minor complications are displayed across the three study groups in Figure 1, *middle*, for perioperative and in Figure 1, *bottom*, for postoperative events.

Heterogeneity

We performed 94 heterogeneity tests (31 complications in two surgical groups and 32 in the percutaneous group). By using a *p* value of .05, only six of 31 tests were compatible with homogeneity in the SgT₁₉₆₀₋₁₉₈₅ group, 10 of 31 in the

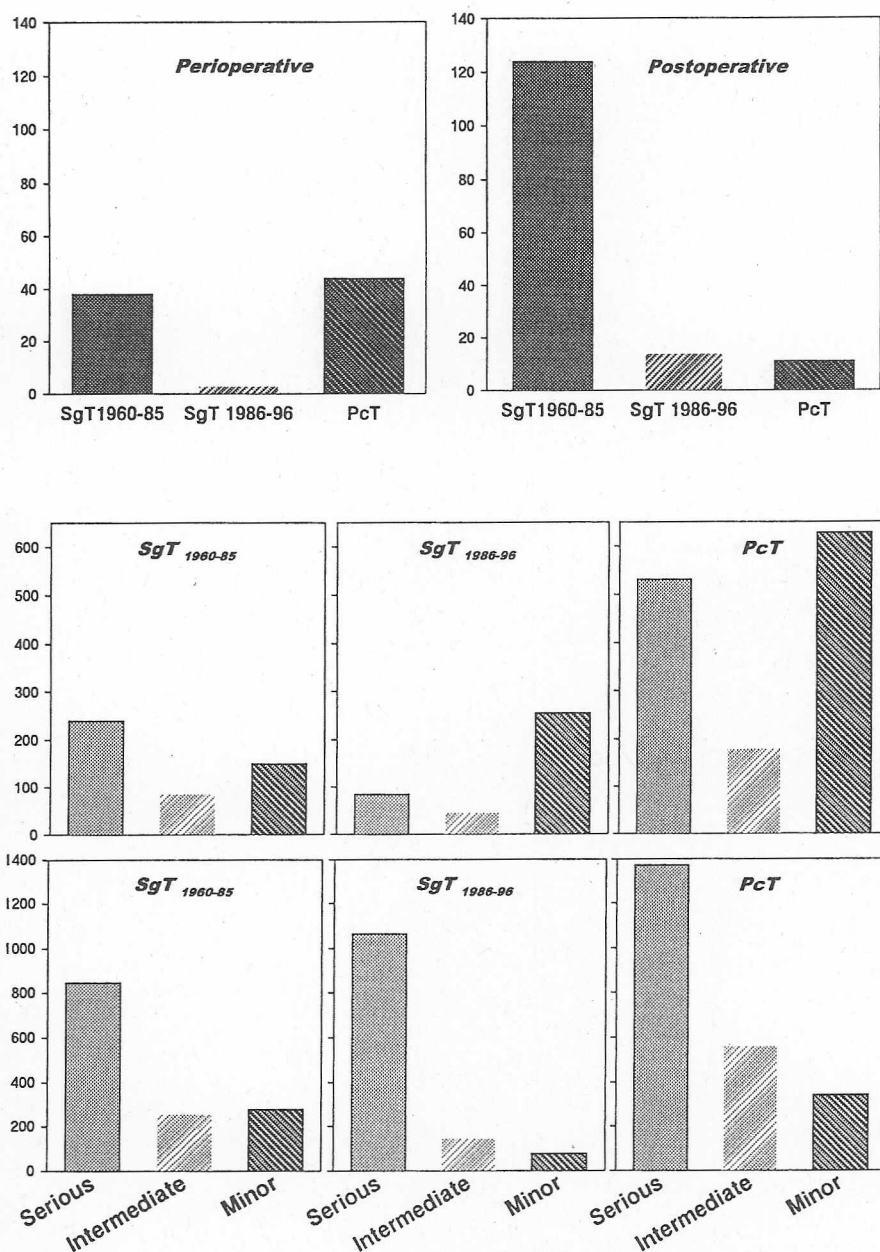


Figure 1. Bar plots of the mortality (top, left and right) and complication rates (middle and bottom) in the tracheostomy literature. The data are grouped in terms of perioperative (top left and middle) and postoperative (top right and bottom) events. The complications have been subdivided into serious, intermediate, and minor (see Tables 2 and 3). SgT, surgical tracheostomy; PcT, percutaneous tracheostomy.

SgT₁₉₈₅₋₁₉₉₆ group, and 18 of 32 in the PcT group. By using the Bonferroni adjusted *p* value of .00055, the corresponding numbers were 12 of 31, 20 of 31, and 27 of 32, respectively. Thus, there was more heterogeneity in the older studies, and more in studies reporting on surgical rather than on percutaneous tracheostomy. Contrary to our expectations, serious complications were not reported in a more homogeneous way (14/39 tests confirmed homogeneity using the 0.05 crite-

rium) than intermediate (11/25) and minor (9/30) complications.

Variations in Mortality over Time

One possible explanation for differences between studies is that the intervention technique and other aspects of health care may change over time. This may be particularly true of recently developed methods, such as percutaneous

tracheostomy. Intraoperative mortality, which may reflect technical problems with the procedure, indeed decreased during the first year when percutaneous tracheostomy was performed (Fig. 2, top). In contrast, postoperative mortality was virtually nil from the start (Fig. 2, bottom). On the other hand, postoperative mortality after surgical tracheostomy has decreased from >1% to zero between 1970 and 1990.

PcT Complications with Different Techniques (Table 4)

Comparison of different PcT methods revealed that techniques not using the progressive dilation technique had the highest complication rates, both perioperatively and postoperatively. Also, the lowest complication rates were found when endoscopic control was used during the progressive dilation technique. The difference reached statistical significance for the intermediate and minor perioperative complication groups.

Individual complications that reached statistical significance between the PcT groups include desaturation, cannula misplacement, difficult tube placement, and false passage for the perioperative complications and pneumothorax as the only postoperative complication.

DISCUSSION

Surgical tracheostomy is a time-established procedure. The advent of the percutaneous tracheostomy technique requires a critical examination of the published data to compare these two tracheostomy techniques. Advantages of PcT, according to PcT advocates, include smaller skin incision (20, 25, 49, 55-58), and less dissection and tissue trauma (20, 21, 24, 49, 55-57, 67, 68), which lead to less hemorrhage (20, 24, 25, 49, 54, 57, 58, 61, 68, 69), fewer infections (20, 24, 25, 49-51, 54-58, 61, 65, 68), fewer tracheal problems (21, 49, 51, 57, 59, 69), and fewer cosmetic deformities (24, 25, 50, 51, 55-57, 59-62, 68). The procedure can be performed at the bedside (20, 25, 26, 51, 53-64, 66-69), decreasing the risk and cost of patient transportation to the operating room (105, 106). PcT is also said to be faster (21, 24, 25, 49-51, 56, 57, 59-62, 64-69) and easier to perform (20, 21, 25, 49, 50, 53, 57, 59, 60, 62-64), to require less personnel (25, 49, 62) and equipment (25, 49, 60, 69), and therefore, is associated with lower cost (50, 53-55, 64, 66, 67, 69). Furthermore, PcT is

Table 3. Postoperative complications, classified as serious, intermediate, and minor, in the three tracheostomy groups

Postoperative Complications	SgT ₁₉₆₀₋₁₉₈₄	SgT ₁₉₆₀₋₁₉₈₄ vs. SgT ₁₉₈₅₋₁₉₉₆	SgT ₁₉₈₅₋₁₉₉₆	SgT ₁₉₈₅₋₁₉₉₆ vs. PcT	PcT
Serious (total)	845	<0.00001 ^a	256	0.72 ^a	278
Death	124	0.00001	14	1.0	11
Tracheoesophageal fistula	31	0.00040	0	0.03960	17
Mediastinitis	12	0.067	0	—	0
Sepsis	24	0.00264	6	0.341	6
Hemorrhage, intratracheal	88	0.00001	71	0.00947	39
Pneumothorax	7	0.00001	0	0.00824	17
Cannula obstruction	251	0.00001	48	0.673	39
Cannula displacement	148	0.02818	91	0.135	50
Tracheal stenosis	160	0.00001	26	0.00073	99
Intermediate (total)	1063	<0.00001 ^a	146	0.052 ^a	78
Pneumonia	650	0.00001	131	0.00001	0
Atelectasis	263	0.00001	3	1.0	6
Aspiration	74	0.00001	9	0.556	0
Tracheal cartilage lesion	76	0.00001	3	0.00001	72
Minor (total)	1372	<0.00001 ^a	561	0.00064 ^a	342
Hemorrhage, external	237	0.657	253	0.180	193
Wound infection	559	0.00001	271	0.00002	99
Tracheitis	480	0.00001	23	0.413	39
Delayed cutaneous closure	38	0.00006	0	—	0
Keloid	22	0.00499	0	0.341	11
Unaesthetic scar	36	0.074	14	1.0	0
Total postoperative complications	3280	<0.00001 ^a	963	0.0024 ^a	698

SgT, surgical tracheostomy; PcT, percutaneous tracheostomy.

Results are expressed as events per 10,000 procedures.

^a*p* Values were computed assuming an independence between complications within each category. If this hypothesis were incorrect, *p* values would be biased toward rejection of the null hypothesis.

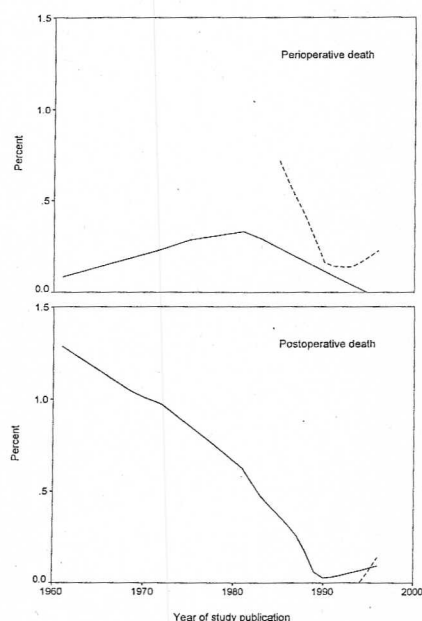


Figure 2. Temporal trends in death rates, perioperative (top) and postoperative (bottom) after surgical (solid line) and percutaneous (dashed line) tracheostomy, based on the 65 analyzed studies and weighted by study sample size. Trends are represented by nonparametric regression lines.

claimed to result in fewer operative and long-term complications (20, 21, 49–51, 53, 54, 56, 57, 59, 60, 62, 64, 66–69). Finally, PcT can be performed by physi-

cians without previous surgical training (54, 56, 58, 60, 63, 64).

Our meta-analysis confirms that PcT is a faster procedure than SgT (11.7 vs. 26.9 mins). Also, a large number of PcT procedures were performed in the ICU, which confirms that the procedure can be performed safely at the bedside and probably argues that PcT is easy to perform. SgT procedures have been performed at the bedside since 1962 (107) and were done in the ICU in 66% of SgT₁₉₈₅₋₁₉₉₆ cases. Therefore, the location of the operation remains largely a matter of personal choice on behalf of the physician.

A comparison of percutaneous tracheostomy with surgical tracheostomy (1960–1984) publications clearly demonstrates that the frequency of most complications is lower with percutaneous tracheostomy. As previously stated, the comparison is probably unfair because of the advances in medical care and, more specifically, in the design of the tracheostomy tubes and cuffs. SgT procedures performed during the last 10 yrs (SgT₁₉₈₅₋₁₉₉₆) are also associated with lower rates of peri- and postoperative complications.

The comparison of PcT with SgT₁₉₈₅₋₁₉₉₆ complication rates is less clear cut. Our results suggest that perioperative compli-

cations are more frequent with PcT, whereas postoperative complications still occur more often with SgT. In general, the bulk of the difference concerns complications we classified as minor (Tables 2 and 3). In terms of perioperative complications, significant differences are found in tracheostomy tube placement, noted as either operative difficulty or tube false passage. This is to be expected, because a SgT procedure proceeds under direct vision to the anterior tracheal wall, whereas PcT remains a “blind” operation. In addition, the most frequently used commercial PcT set uses a series of 10 dilators of progressively larger diameter to create a passage of the appropriate size, allowing for the introduction of the tracheostomy cannula. These numerous manipulations may lead to displacement of the guidewire tip in the pretracheal tissues and the creation of a false passage. Another minor perioperative complication, reported with a significantly higher frequency with PcT, is subcutaneous emphysema. This could be attributable to the tight fit of the dissected pretracheal tissue around the tracheostomy cannula, which prevents the escape of tracheal air through the skin incision.

The tight fit of the tracheostomy cannula to the surgical tract probably ex-

Table 4. Peri- and postoperative complications, classified as serious, intermediate, and minor, in the three percutaneous tracheostomy (PcT) groups

	PDT-PcT	PDT-PcT with Endoscopic Control	Other PcT	Fischer's Exact Test
No. of studies	17	5	5	
References	20, 25–27, 50–52, 54, 55, 57, 58, 60, 61, 65, 66, 68, 69	53, 62–64, 67	21, 24, 49, 56, 59	
No. of patients	1123	373	321	
Serious perioperative	125	107	281	0.12 ^a
Intermediate perioperative	205	134	561	0.0013 ^a
Minor perioperative	534	241	1401	<0.0001 ^a
Total perioperative complications	864	482	2243	<0.0001 ^a
Serious postoperative	294	134	374	0.11 ^a
Intermediate postoperative	89	27	125	0.29 ^a
Minor postoperative	392	375	156	0.10 ^a
Total postoperative complications	775	536	655	0.29 ^a

PDT, progressive dilation technique; PcT, percutaneous tracheostomy.

Results are expressed as events per 10,000 procedures.

^a *p* Values were computed assuming an independence between complications within each category. If this hypothesis were incorrect, *p* values would be biased toward rejection of the null hypothesis.

plains the difference in minor postoperative complications favoring the PcT technique. The tamponade of small vessels reduces external hemorrhage, and the lesser tissue dissection and exposure in the tracheostomy wound might explain the lower rates of wound infections. Therefore, our analysis tends to support claims that PcT causes less tissue trauma, wound infections, and bleeding. In contrast, fewer tracheal problems (tracheal stenosis and tracheal cartilage lesions) occur in SgT_{1985–1996} data relative to PcT.

Probably the most troublesome differences between PcT and SgT_{1985–1996} are in serious perioperative complications. Significant differences are present in terms of operative mortality and cardiorespiratory arrest, with totals of 77 per 10,000 for PcT and 9 per 10,000 with SgT_{1985–1996}. Whether the learning curve of a new technique, as shown in Figure 2, *top*, is the only explanation remains to be demonstrated. Contributing factors may include a false passage, posterior tracheal wall lesions with resulting tracheoesophageal fistulas, and the “blind” nature of PcT dissection. However, patients in the ICU, who tend to be included more often in PcT articles, probably have inherently higher complication rates.

Published studies on complications of tracheostomy exhibited substantial heterogeneity, even within groups of studies that reported on similar procedures. Adequate data to explain between-study variations were not available. Plausible hypotheses include differences in patient

populations, intervention technique, surgical skills, effectiveness of supportive services, choice of relevant complications, methods to assess complication occurrence, reporting format, and selective publication. The same variables that engender heterogeneity may also cause confounding in comparisons of the three study groups. Thus, all results presented in this analysis should be taken with caution because the heterogeneity analysis suggests that not all observed differences were attributable to intervention technique.

For example, the subset analysis of different PcT showed different complication rates. The lowest complication rates were obtained with the progressive dilation method (20) performed under endoscopic control (53). Nonprogressive dilation PcT techniques had the highest number of complications. Nevertheless, even when the PcT technique associated with the lowest complication rates, namely the endoscopically controlled progressive dilation technique, is compared with SgT_{1985–1996} data, the trend discussed earlier is confirmed: lower perioperative complications with SgT and lower postoperative complication rates with PcT.

Despite this heterogeneity of the studies included in each group, the claims of lower complication rates with PcT relative to SgT found in numerous publications (20, 21, 49–51, 53, 54, 56, 57, 59, 60, 62, 64, 66–69) seem unwarranted, when studies conducted during the same

A comparison of percutaneous tracheostomy with surgical tracheostomy (1960–1984) publications clearly demonstrates that the frequency of most complications is lower with percutaneous tracheostomy.

time frame are compared. Only prospective randomized trials, with a blinded evaluation of the individual complications can definitively answer this question. Such trials are as yet to be published (108). Previous comparative studies are retrospective (26, 60), nonrandomized (24, 26, 56, 60, 64), or not evaluated by an observer blinded as to the surgical technique (57, 65, 68). However, because complications of tracheostomy are rare, the size of such a trial may be prohibitive.

Even though its superiority over SgT is not established, PcT is being reported and probably used with increasing frequency. The reported complication rates in 27 studies of almost 2,000 patients who have undergone the procedure are not prohibitive and compare favorably with complication rates of SgT published only 10 yrs ago. Most of the studies use one commercial PcT set, and future improvements in the devices used might render the technique even safer.

In conclusion, the available data suggest the following: a) PcT is not clearly superior to SgT when recent studies are compared; b) PcT is associated with more perioperative complications than SgT in the published articles; c) PcT compares favorably with SgT in terms of postoperative problems. However, these conclusions should be accepted with caution because of the heterogeneity of studies published and because of the difficulty in detecting real differences when the prevalence of complications is low. The choice of the tracheostomy technique should be based on personal experience, until compelling evidence favoring one technique becomes available.

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