Anastomotic complications after tracheal resection: Prognostic factors and management

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Objective: We sought to identify risk factors for anastomotic complications after tracheal resection and to describe the management of these patients.

Methods: This was a single-institution, retrospective review of 901 patients who underwent tracheal resection.

Results: The indications for tracheal resection were postintubation tracheal stenosis in 589 patients, tumor in 208, idiopathic laryngotracheal stenosis in 83, and tracheoesophageal fistula in 21. Anastomotic complications occurred in 81 patients (9%). Eleven patients (1%) died after operation, 6 of anastomotic complications and 5 of other causes (odds ratio 13.0, P = .0001 for risk of death after anastomotic complication). At the end of treatment, 853 patients (95%) had a good result, whereas 37 patients (4%) had an airway maintained by tracheostomy or T-tube. The treatments of patients with an anastomotic complication were as follows: multiple dilations (n = 2), temporary tracheostomy (n = 7), temporary T-tube (n = 16), permanent tracheostomy (n = 14), permanent T-tube (n = 20), and reoperation (n = 16). Stepwise multivariable analysis revealed the following predictors of anastomotic complications: reoperation (odds ratio 3.03, 95% confidence interval 1.69-5.43, P = .002), diabetes (odds ratio 3.32, 95% confidence interval 1.76-6.26, P = .002), lengthy (≥4 cm) resections (odds ratio 2.01, 95% confidence interval 1.21-3.35, P = .007), laryngotracheal resection (odds ratio 1.80, 95% confidence interval 1.07-3.01, P = .03), age 17 years or younger (odds ratio 2.26, 95% confidence interval 1.09-4.68, P = .03), and need for tracheostomy before operation (odds ratio 1.79, 95% confidence interval 1.03-3.14, P = .04).

Conclusions: Tracheal resection is usually successful and has a low mortality. Anastomotic complications are uncommon, and important risk factors are reoperation, diabetes, lengthy resections, laryngotracheal resections, young age (pediatric patients), and the need for tracheostomy before operation.

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Anastomotic complications after tracheal resection and reconstruction are uncommon but lead to severe morbidity.[1,2] Anastomotic complications include granulations at the anastomotic line (presumably some degree of separation allows ingrowth of granulation tissue between the two cut edges of the divided trachea), stenosis (distraction of the tracheal anastomosis allows scar to develop at the suture line), and separation (disruption of the suture line causes a

TABLE 1. Patient characteristics

Variable	Overall (n = 901)	PITS (n = 589)	TEF (n = 21)	ILTS (n = 83)	Tumor (n = 208)	*P* value
Age						<.0001
Mean ± SD	47.4 ± 18.9	44.1 ± 19.6	41.1 ± 21	46.5 ± 12.2	55.8 ± 15.9	
Range	4-86					
Age ≤ 17 y (No.)	62 (6.9%)	55 (9.3%)	3 (14.3%)	0	4 (2.0%)	.0001
Male (No.)	432 (48.0%)	314 (53.3%)	8 (38.1%)	2 (2.4%)	108 (52.0%)	<.0001
Height (m, mean ± SD)	1.66 ± 0.12	1.66 ± 0.13	1.61 ± 0.3	1.62 ± 0.08	1.68 ± 0.10	.0009
BMI (kg/m^2)						.02
Mean ± SD	26.5 ± 6.1	26.7 ± 6.6	23.3 ± 47	27.7 ± 6.6	26.0 ± 4.5	
Range	14-60					
Obese (No.)	219 (25.2%)	150 (26.7%)	3 (14.3%)	26 (31.7%)	40 (19.6%)	.06
Hemoglobin (gm/dL, mean ± SD)	13.5 ± 1.4	13.6 ± 1.4	12.4 ± 14	13.2 ± 1.3	13.5 ± 1.4	.0008
Steroids (No.)	63 (7.0%)	43 (7.3%)	1 (4.8%)	3 (3.6%)	16 (7.7%)	.004
Diabetes (No.)	96 (10.7%)	73 (12.4%)	8 (38.1%)	5 (6.0%)	10 (4.8%)	<.0001
Late time (No.)	452 (50.2%)	254 (43.1%)	10 (47.6%)	67 (80.7%)	121 (58.1%)	<.0001
Preoperative tracheostomy (No.)	276 (30.6%)	251 (42.6%)	15 (71.4%)	5 (6.0%)	5 (2.4%)	<.0001
Reoperation (No.)	101 (11.2%)	85 (14.4%)	9 (42.9%)	3 (3.6%)	4 (2.0%)	<.0001
Approach (No.)						<.0001
Cervical	676 (75)	469 (79.6)	18 (85.7)	82 (98.8)	107 (51.4)	
Mediastinal	180 (20.0)	117 (20.0)	3 (14.3)	1 (1.2)	59 (28.4)	
Thoracic	45 (5.0)	3 (0.5)	0	0	42 (20.2)	
Length						<.0001
Mean ± SD	3.3 ± 1	3.3 ± 1	3.8 ± 0.8	2.7 ± 0.5	3.5 ± 1	
Range	1-6.5					
Length ≥4 cm (No.)	279 (31)	175 (29.7)	12 (57.1)	3 (3.6)	89 (42.8)	<.0001
Release (No.)	81 (9.0)	50 (8.5)	5 (23.8)	1 (1.2)	25 (12.0)	.002
Laryngotracheal resection (No.)	281 (31.2)	141 (23.9)	4 (19.1)	83 (100)	53 (25.5)	<.0001
Postoperative tracheostomy (No.)	71 (8.0)	54 (9.2)	4 (19.1)	5 (6.0)	8 (3.9)	.02

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catastrophic failure of the anastomosis). Previous human cadaver studies have demonstrated a progressive rise in tension at the anastomosis with increasing length of tracheal resection, suggesting a safe limit of 4.5 cm (corresponding to about 1000 g tension) to avoid anastomotic failure.[3,4] Acceptable anastomotic tension is learned with experience. Early attempts at precise intraoperative measurement of anastomotic tension proved difficult and imprecise. Short resections are relatively straightforward, but lengthy resections are fraught with possible difficulty, especially for the occasional tracheal surgeon. A previous report from our unit in 1995 on patients with postintubation tracheal stenosis (PITS) suggested that reoperations and laryngotracheal anastomosis were associated with a higher failure rate.[5] The influences of length of resection and other possible prognostic factors were not addressed, and no statistical analysis of any variable was performed. Reports of tracheal resections usually include small numbers of patients, and there have been no multivariate analyses of prognostic factors for anastomotic complications. Detailed reports on the management and results of treatment of anastomotic complications are not available. We sought to clarify these issues by analyzing our large experience with tracheal resections for the most common indications: PITS, tracheoesophageal fistula (TEF), tumor, and idiopathic laryngotracheal stenosis (ILTS).

Patients and Methods

Patients

A retrospective review of 901 patients undergoing tracheal resection and reconstruction from January 1, 1975, to December 31, 2003, in our hospital for the diagnoses PITS, TEF, tumor, and ILTS was performed. Rare diagnoses for tracheal resection were excluded from review to allow comparison of results among the major diagnoses. We excluded resections that involved the carina, because carinal resections present a unique complication profile. Approval for this study was obtained from the human research committee. Hospital and office charts were reviewed to abstract pertinent information, and a database was constructed (Table 1). Five patients' charts could not be located, so their data were dropped from the data set. Thirty-three patients did not have height and weight recorded, but otherwise the data set was complete.

Patient Management

The preoperative evaluation, patient selection, and operative techniques used have been detailed in previous reports from our unit.[5-10] Two management details that have changed during the

TABLE 2. Results of treatment

Variable	Overall (n = 901)	PITS (n = 589)	TEF (n = 21)	ILTS (n = 83)	Tumor (n = 208)	*P* value
Stay (d)						<.0001
Median	8	8	10	7	8	
Interquartile range	7-11	7-11	16-21	7-8	7-11	
Complications (No.)	164 (18.2%)	109 (18.5%)	6 (28.6%)	8 (6.6%)	41 (19.7%)	.11
Anastomotic complications (No.)	81 (9%)	65 (11%)	3 (14.3%)	2 (2.4%)	11 (5.3%)	.009
Death (No.)	11 (1.2%)	8 (1.4%)	1 (4.8)	0	2 (1%)	.02
Result (No.)						.04
Good	853 (95%)	553 (95.2%)	18 (90%)	82 (98.8%)	200 (97.1%)	
Tube	37 (4.2%)	28 (4.8%)	2 (10%)	1 (1.2%)	6 (2.9%)	

TABLE 3. Univariable analysis of predictors of anastomotic complications

Variable	No separation (n = 820, 91%)	Separation (n = 81, 9%)	Univariable odds ratio	95% Confidence interval	*P* value
Age (y, mean ± SD)	47.4 ± 18.7	42.3 ± 20.3	0.99	0.97-1.00	.02
Age ≤ 17 y (No.)	49 (6%)	13 (16%)	3.0	1.56-5.82	.0006
Male (No.)	382 (46.6%)	50 (61.7%)	1.85	1.16-2.95	.009
Height ± SD	1.66 ± 0.11	1.65 ± 0.16	0.40	0.06-2.61	.47
BMI (kg/m^2, mean ± SD)	26.4 ± 5.9	27.8 ± 8.2	1.04	1.00-1.07	.14
Obese (No.)	195 (24.7%)	24 (30.4%)	1.33	0.80-2.20	.27
Steroids (No.)	59 (7.2%)	4 (4.9%)	0.67	0.23-1.89	.65
Diabetes (No.)	78 (9.5%)	18 (22.2%)	2.72	1.53-4.82	.0004
Late time (No.)	405 (49.3%)	47 (58%)	1.42	0.89-2.25	.14
Stenosis* (No.)	542 (66.1%)	68 (84%)	2.68	1.46-4.94	.001
Preop tracheostomy (No.)	232 (28.3%)	44 (54.3%)	3.01	1.89-4.79	<.0001
Reoperation (No.)	77 (9.4%)	24 (29.6%)	4.06	2.39-6.91	<.0001
Approach (No.)					.59
Cervical	612 (74.6%)	64 (79%)	1.28	0.73-2.23	
Mediastinal	165 (20.1%)	15 (18.5%)	0.90	0.50-1.62	
Thoracic	43 (5.2%)	2 (2.5%)	0.46	0.11-1.92	
Length ± SD	3.25 ± 0.9	3.72 ± 1.1	1.61	1.28-2.02	.0005
Length ≥4 cm (No.)	238 (29%)	41 (50.6%)	2.51	1.58-3.97	<.0001
Release (No.)	59 (7.2%)	22 (27.2%)	4.81	2.76-8.39	<.0001
Laryngotracheal resection (No.)	248 (30.2%)	33 (40.7%)	1.59	0.99-2.53	.05
Postoperative tracheostomy (No.)	56 (6.8%)	15 (18.5%)	3.10	1.66-5.78	.0002

*PITS and TEF as a diagnosis group.

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lengthy period of this review bear emphasis. Nonabsorbable Tevdek (Deknatel, Inc, Fall River, Mass) polyester sutures and other nonabsorbable sutures were used to construct anastomoses before 1978, which led to repeated bronchoscopic suture removal and local steroid injection with a high rate of success. Absorbable Vicryl (Ethicon, Inc, Somerville, NJ) polyglactin sutures have been used since 1978 and have all but eliminated suture-related granulations.[5] Tracheal anastomoses were routinely covered with pedicled local tissue if the innominate artery was close to the anastomosis. Anastomotic integrity was routinely evaluated in every patient with postoperative tracheal tomograms about 1 week after operation until 1995. Starting in 1995, routine postoperative surveillance bronchoscopy was instituted instead of tomograms to ensure anastomotic integrity before discharge. This change in surveillance followed a few cases with negative tomographic results but positive bronchoscopic findings of either marginal necrosis (indicating impending separation or stenosis) or minor separation. We believe that this change in management will lead to earlier identification and treatment of anastomotic complications.

Outcome Variables

The primary outcome variable was an anastomotic complication that required treatment. Anastomotic complications were grouped into three main categories: (1) granulation at the anastomosis requiring multiple bronchoscopic débridements, an airway appliance or reoperative resection, thought to be the result of partial or complete separation (minor granulations from polyester sutures were not coded as an anastomotic complication); (2) stenosis at the anastomosis causing symptoms or leading to reintervention, such

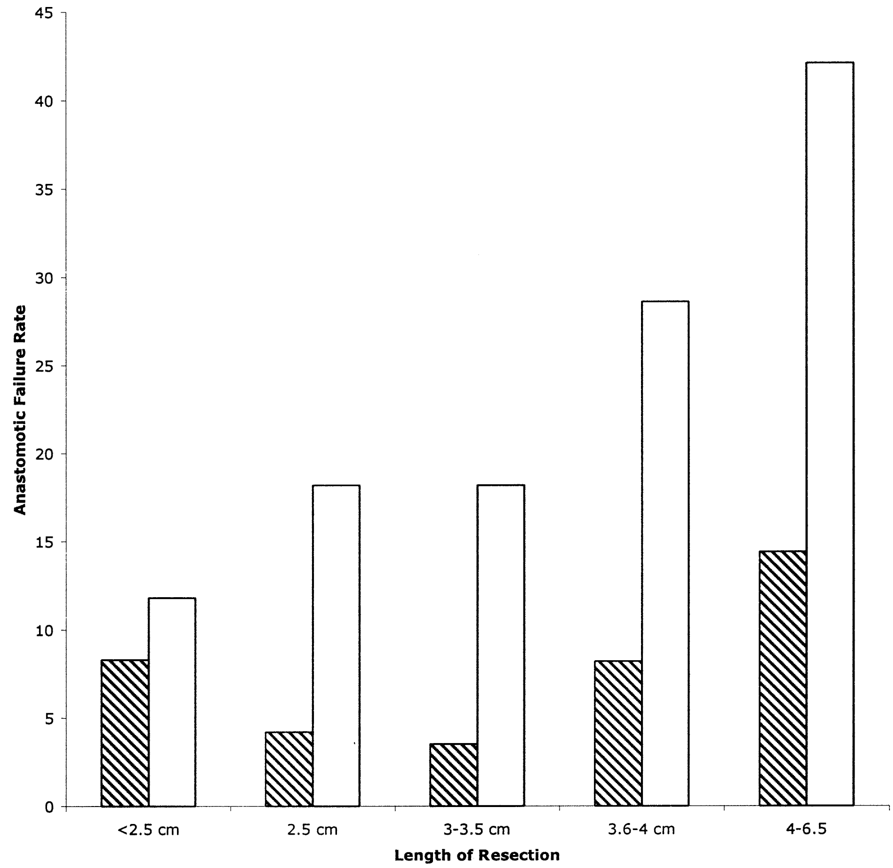

Figure 1. Anastomotic complication rate as function of length of resection in patients undergoing first resection (n = 800, *diagonally striped bars*) and reoperation (n = 101, *solid bars*). Lengths are presented as quintiles.

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TABLE 4. Multivariable analysis of predictors of anastomotic complications

Variable	Odds ratio	95% Confidence interval	*P* value
Diagnosis			
PITS	1.00	—	
TEF	0.54	0.14-2.01	.35
ILTS	0.31	0.07-1.40	.13
Tumor	0.85	0.39-1.82	.67
Length ≥4 cm	2.01	1.21-3.35	.007
Preoperative tracheostomy	1.79	1.03-3.14	.04
Age ≤17 y	2.26	1.09-4.68	.03
Diabetes	3.32	1.76-6.26	.002
Reoperation	3.03	1.69-5.43	.002
Laryngotracheal resection	1.80	1.07-3.01	.03

as multiple dilations, an airway appliance, or reoperation; and (3) separation at the anastomosis that required either an airway appliance or reoperation. Secondary outcome variables were the need for a postoperative airway appliance, other major complications, length of hospital stay, and postoperative death.

Demographic and Clinical Variables

The following variables were entered into the data set and evaluated for possible association with anastomotic complications: age, sex, diagnosis, height, body mass index (BMI), diabetes mellitus (defined as diabetes requiring medication), corticosteroid use (defined as the use of prednisone at >10 mg/d within 1 week of operation), hemoglobin level, the presence of either a tracheostomy tube or T-tube before the operation, whether the operation was a reoperation, year of operation, incisional approach (cervical, cervicomediastinal, or transthoracic), length of resection, whether a tracheal or laryngotracheal resection was performed, whether a suprahyoid laryngeal release was required, whether a postoperative tracheostomy was required, the status of the airway at the end of treatment, the length of stay, and death after operation. Several continuous variables were recoded into categoric variables when clinically appropriate: pediatric patients were coded as aged 17 years or younger to reflect the commonly accepted range of pediatric surgery, BMI of at least 30 kg/m^2 was coded as obese to reflect a common clinical definition of obesity, operation date was recoded into early (≤1989) and late (≥1990) to reflect possible learning effects and contemporary practice, and length of resection was recoded into short (<4 cm) and long (≥4 cm) to reflect both a clinically and statistically relevant estimate of lengthy resections.

Statistical Methods

All statistical testing was performed with SAS software (SAS version 8; SAS Institute Inc, Cary, NC). Continuous variables were analyzed with the *t* test, analysis of variance, or Wilcoxon rank sum test. Categoric variables were analyzed with the χ^2 and Fisher exact tests. The form of continuous variables was assessed with categoric dummy variables (as quartiles, quintiles, or deciles) to assess linearity with the outcome of anastomotic complications and to determine a meaningful cut point where appropriate. Stepwise multivariable logistic regression analysis was used to test for predictors of anastomotic complications, with entry and stay criteria of .10 and .05, respectively. Clinical variables were considered as candidates for inclusion if significant to $P < .10$ in univariate testing. Preoperative diagnosis was initially collapsed into PITS and TEF versus ILTS and tumor but was ultimately retained in the model as categoric for each individual diagnosis to reduce confounding, although neither form of this information was significant. Suprahyoid laryngeal release was not included as a candidate variable. Interactions between all the main effects in the final model were assessed with the hierarchic principle, and none were significant. To assess for overfitting, the multivariable model was bootstrapped to 1000 iterations, forcing in only those covariates in the final model; means of the SEs for each parameter estimate were used in a χ^2 test with the original parameter estimate. The Hosmer-Lemeshow test was used to confirm the goodness of fit of the model. A similar model was constructed excluding the patients with ILTS.

Propensity analysis was performed for better assessment of the importance of suprahyoid release as a predictor of anastomotic complications. First, a logistic regression model for release was constructed with the following clinical variables: sex, pediatric age, BMI greater than 30 kg/m^2, height, diabetes, steroid use, preoperative tracheostomy, reoperation, continuous date of operation, continuous resection length, quintiles of resection length, surgical approach, postoperative airway, and laryngotracheal resection. Propensity scores were calculated from the model to predict likelihood of release on the basis of these clinical variables, and these were included along with the binary release covariate in a separate logistic model of anastomotic complications. Then χ^2 tests of release by this outcome, stratified into deciles of the propensity score, yielded Mantel-Haenszel odds ratios with essentially identical results. With improved coding for length (using deciles), the significance of release was attenuated to $P = .04$, and we expect that there may still be some residual confounding. On the basis of this analysis, and because of we recognized that release was obviously highly correlated with length and reoperation, among other factors, we excluded release from the original multivariable model of anastomotic complications.

Results

The baseline characteristics of the patients, grouped by diagnosis and as the overall population, are presented in Table 1. By and large the patients were similar clinically among the different diagnoses, with a few notable exceptions. Patients with PITS and TEF were more likely to have a tracheostomy before operation. Patients with ILTS were almost all women who had relatively short resections that involved the larynx. Patients with tumors were older and had more lengthy resections. Patients with PITS and TEF were consolidated into a single diagnostic group category of stenosis because of the single etiology and inflammatory nature of the obstructive disease, as well as similar rates of anastomotic separation (11.2% for PITS and TEF) higher than in either the tumor (5.3%) or ILTS (2.4%) group. The results of treatment are presented in Table 2. Ninety-five percent of patients had a good result from their airway surgery at the end of treatment, with no need for an airway appliance (tracheostomy tube or T-tube). Only 4% of patients had a permanent airway appliance, and only 1.2% died. Anastomotic complications were most frequent in the TEF group and least in the ILTS group. Complications (other, such as pneumonia) were most frequent among patients with TEF (the most complex group) and least among patients with ILTS, as expected.

The univariate analysis of predictors of separation is presented in Table 3. The diagnostic groups of PITS and TEF were combined and then compared with the other two combined diagnostic groups (ILTS and tumor) to establish a lower-risk reference group with which to compare the patients with stenosis. Several variables were obviously clinically related, which confounds the univariate analysis. For example, tracheostomy before operation was highly correlated with the diagnoses of PITS and TEF, as one would expect. Another is that the TEF group, the most difficult diagnosis to manage, had numerous high-risk variables associated with it: longer resections, more reoperations, more frequent need for laryngeal release for excessive tension, and more frequent diabetes. Obesity (BMI ≥30 kg/m^2) did not appear to be a risk factor for anastomotic complications, but patients who were very obese (BMI ≥35 kg/m^2, n = 83) did have a trend toward higher risk ($P = .07$).

Figure 1 illustrates the relationship between length of resection (tension) and the anastomotic failure rates among patients undergoing first resection and reoperation. Resections longer than 4 cm were associated with a dramatic rise in the rate of failure. Among patients undergoing first-time surgery, the fourth quartile of resection length (≥4 cm) was associated with twice the risk of anastomotic complication (odds ratio 2.04, 95% confidence interval 1.04-3.99]) compared to the lowest quartile; with reoperation, this result is similar (odds ratio 4.35, 95% confidence interval 1.08-17.63) for the fourth (≥4.5 cm) versus the lowest quartile of length. Note that in patients undergoing reoperation not only did the rate of complications increase with length of resection, but the failure rate at all lengths but the smallest was more than double that for primary resections.

The stepwise multivariable analysis of predictors of anastomotic complications is seen in Table 4. Reoperation and diabetes were the most predictive indicators of compli-

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cations. A bootstrap analysis (n = 1000) was performed, and all variables in our model remained significant. Goodness of fit of the model was confirmed with the Hosmer-Lemeshow test. The c-statistic for the model was 0.73. We repeated the multivariable analysis excluding the good-risk patients with ILTS to make sure that we were not biasing the study by including these patients, but there was no difference in the variables identified as significant in our model. We decided against allowing need for laryngeal release into the model because it was highly correlated with other underlying clinical covariates and it could be misconstrued that a release caused the complication; in reality the surgeon's judgment is that without a release the risk would be close to 100%. There is no question that the need for a release indicates a high-risk case, and indeed a preliminary multivariable analysis indicated it had an odds ratio of 3. Propensity scoring for the need for a release was undertaken. This analysis indicated that other clinical covariates, coded as the propensity score for the need for a release, accounted for greater than a 16-fold increase in risk (P = .0002), whereas the importance of the release was largely attenuated.

Patients with anastomotic complications were treated in a graded fashion, depending on the nature and severity of the problem. Patients with an anastomotic complication were categorized into three groups, depending on the primary reason for failure: (1) separation of the suture line (n = 37), (2) stenosis at the anastomosis (n = 37), and (3) granulations causing obstruction at the anastomosis (n = 7). Treatments for surviving patients were as follows: multiple dilations (n = 2), temporary tracheostomy (n = 7), temporary T-tube (n = 16), permanent tracheostomy (n = 14), permanent T-tube (n = 20), and reoperation (n = 16). All patients who underwent reoperation had a satisfactory result. Of the 81 patients with an anastomotic complication, 41 (51%) had a satisfactory airway without need for an artificial airway by reintervention. Three patients (0.3%) had TEF develop as a result of an anastomotic complication. Six patients died as a result of anastomotic separation: 3 died of anoxia from airway obstruction, 2 died after repair of a tracheoinnominate artery fistula, and 1 died of mediastinitis. The mortality among patients who had anastomotic complications was 7.4% (6/81), whereas it was 0.01% (5/820) among those without anastomotic complications (odds ratio 13.0, P = .0001). The causes of death among the patients without anastomotic complications were aspiration pneumonia (n = 3), myocardial infarction (n = 1), and pulmonary embolism (n = 1). All the patients who died after an anastomotic complication died in the early years, with the last death in 1988. The median stays were 8 days without an anastomotic complication and 14 days with an anastomotic complication ($P < .0001$).

Discussion

In this study we sought to quantitatively identify true risk factors and determine predictors of anastomotic failure. The multivariable analysis demonstrated that diabetes, reoperation, longer resections, young age (pediatric patients), need for tracheostomy before the operation, and laryngotracheal resection were associated with anastomotic complications. The need for a suprahyoid release is a potentially confusing factor and should not be misinterpreted as a procedure that regularly prevents an anastomotic complication. The surgeon performs a release when in his judgement reapproximation of the divided ends of the trachea would produce anastomotic tension so great that anastomotic failure would be likely. In the hands of an experienced surgeon, the perceived need for a release is a most reliable marker of otherwise excessive tension. An alternative way to view release as a variable would be that the anastomotic complication rate would be expected to be 100% when a release was deemed necessary but was only 25% (22/81) when a release was performed, a substantial risk reduction. Reoperation as a risk factor is clinically intuitively obvious, because previous tracheal resection would translate to an increased anastomotic tension at the subsequent resection, although experience has shown that successive resections at intervals are not simply additive by length. The dense surrounding peritracheal fibrosis from previous operation militates against success, however, because it limits tracheal mobility and may increase tension. Despite the elevated risk, reoperation is usually successful (75%, 77/101) if patients are selected carefully.[7]

Diabetes is a surprisingly important risk factor for anastomotic complication, with an odds ratio of 3.[3]. This may be a consequence of impairment of an already compromised collateral watershed circulation at the end of the divided trachea. Tension might be expected to put this area at further risk. Diabetes is known to impair the microcirculation, with resultant deleterious effects on wound healing. Unfortunately, this risk factor cannot be modified, but it should be taken into account in stratifying risk. The fact that patients with longer resections are at increased risk is no surprise. Grillo and colleagues[3] documented an exponential rise in tension with increasing length of resection in cadavers, and Cantrell and associates[11] did the same experimentally in animals. These results mirror what is seen clinically, as illustrated in Figure 1. There can be no absolute guidelines to limits of resection in an individual patient, but prudence dictates that patients undergoing resections longer than 4 cm should be considered for a release procedure. Pediatric patients have long been thought to tolerate tension less well than adults. Puppies have been shown to tolerate anastomotic tension less well than dogs.[12] Recent analysis of our pediatric experience in tracheal surgery confirmed the original supposition that only about 30% of the juvenile trachea can be resected before encountering increased anastomotic failure rates.[13] This study confirms those findings relative to adults, with an odds ratio of 2.3. We have long thought on the basis of clinical observation that patients with postintubation lesions (PITS and TEF) are more difficult to deal with than are patients with ILTS or tumors. This intuition was corroborated by the univariable analysis but not the final multivariable analysis. Need for a tracheostomy before operation was an independent risk factor, with an odds ratio of 1.8, but in essence was a marker for a particularly difficult cases of PITS, because patients with tumor and ILTS rarely had a previous tracheostomy. Patients with stenosis tend to have gradations of injury to the trachea that make difficult the choices in lengthy resections of what degree of residual airway injury to accept to limit anastomotic tension. Most lengthy resections have some degree of mucosal or cartilaginous abnormalities remaining, which can pose a problem with anastomotic healing. Patients with stenosis often have peritracheal inflammation, beyond the maximal stenosis that is resected, which may limit mobility for reapproximation. A laryngotracheal resection with anastomosis to the larynx was also associated with a higher anastomotic failure rate, with an odds ratio of 1.8. A laryngeal anastomosis is always more delicate to perform and seems less robust than tracheotracheal anastomoses. When laryngotracheal resections are required in patients with stenosis, this becomes another surrogate marker of severe disease with injury at two levels of the airway. We initially reported this in a rudimentary univariable analysis of only patients with stenosis with an almost 4-fold increased failure rate of laryngotracheal anastomoses relative to tracheotracheal anastomoses.[5]

Contrary to our expectations, obesity was not a risk factor, although patients who were very obese (BMI > 35 kg/m^2) did have a trend toward more anastomotic failure ($P = .07$). Because most of our patients with diabetes had type 2 disease, many of them were obese, and this association may have explained our clinical intuition. Also contrary to our expectation, steroid use did not seem to be associated with anastomotic complications. Our policy has long been to attempt to wean referred patients from corticosteroids, because these drugs do not improve critical airway stenosis and may impair wound healing and increase infectious complications. Because of slow attenuation of anastomosis and restenosis in 2 patients who underwent limited tracheal resection while receiving high-dose corticosteroids, such patients usually have the operation deferred until they have been weaned to very low or zero dosage. This management strategy probably influenced our results, because many of our patients were weaned from steroids before resection. The patients who were resected while receiving steroids were almost always receiving rather low doses for a brief course. Patients receiving steroids who must be operated on should otherwise be at low risk, and especial care should be taken with the anastomosis, including buttressing it with local muscle flaps.

We explored the influence of date of operation on outcome, expecting a possible learning curve effect. A steady decline in mortality has been recorded in tracheal and carinal resection for squamous and adenoidcystic carcinoma.[14] On the contrary, in operations after 1990 univariable analysis showed an increased number of anastomotic complications. This probably represents acceptance of more challenging cases because of increasing experience.

The management of patients with an anastomotic complication was necessarily individual, but broad conclusions can be proposed. Early diagnosis is important to avoid asphyxiation and severe infectious complications. Routine bronchoscopy before discharge contributes to finding early anastomotic complications, which are easier to manage before severe infectious or obstructive problems ensue. The mortality associated with anastomotic failure seems remarkably low (7.4%), and no patients have died since 1988. This probably reflects earlier diagnosis and definitive management of this complication. If the diagnosis is suspected in a patient with a stable airway, a CT scan of the neck and chest should be performed to search for extratracheal air and fluid collections and to clarify the relationship of the anastomosis to the brachiocephalic artery. The next step is to examine the anastomosis by bronchoscopy, noting the quality of the residual airway and the status of the subglottic larynx and glottis. It is rare that secure resuture of the anastomosis would be likely in acute separation, except in the rare case of a short resection that dehisced because of violent coughing or sudden hyperextension. We believe that the best option is usually to control the airway by tracheostomy tube or T-tube, to drain any associated infectious collections, and to provide antibiotics and general supportive care. A T-tube is always preferred because it allows speech and normal airway humidification, and the resulting stomal area is invariably less damaged than with tracheostomy. If there are glottic or subglottic abnormalites, or if the patient requires ventilation, a tracheostomy is needed. In rare cases mild to moderate anastomotic stenosis, especially when involving only part of anastomotic circumference, may permanently respond to bronchoscopic dilations. It is a mistake to reoperate too early once the patient has recovered from initial management of the complication. We generally wait at least 6 months and sometimes a year to allow maximal resolution of peritracheal inflammation. Patients who are carefully selected for reoperation have a high chance of success in achieving a satisfactory airway. In a few cases, limited separation has healed by end-to-end contraction over a silicone stent, T-tube, or T-Y–tube, with no further procedures or stents required. About half of the patients can have

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a relatively normal airway returned by temporary stenting, dilations, or reoperation.

There are several limitations of our study. These include that it is retrospective, that it is based on a single institution's experience, and that it spans a relatively long period. Biases in referral patterns might make this a unique data set from which it would be hard to extrapolate. Subtle but important selection factors used by surgeons to decide on operation as the correct treatment modality are hard to quantify or even identify. Many of the examined variables are highly correlated, and it remains problematic to sort out their relationships and order of importance. Despite these reservations, this report is based on enough patients to provide a multivariable analysis with reasonable power.

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Discussion

Dr Ernio Angelo Rendina *(Rome, Italy).* Dr Wright, I congratulate you and your colleagues on an excellent presentation. Certainly the statement that you often repeat, that complications are uncommon after tracheal resection, applies to no other group better than to yours, and 95% good results speak for themselves. As you honestly point out in your article, there are limitations to this study because your group of patients is unique, and extrapolation is difficult. Nevertheless, the contribution of this article is remarkable, and your quantitative demonstration of risk factors is the ultimate answer to this question.

I would like to comment briefly on the length of resection as a function of anastomotic tension. In this context, fibrous retracting strictures causing a stretching of the remaining trachea are very different from loose, malacic stenoses allowing the healthy trachea to recoil on itself.

In the first case, the healthy trachea is already tractioned beforehand, whereas in the second case, it is rather the normal elasticity of the trachea that tends to elongate the stenosis. Stenoses of the same length do therefore not imply necessarily the same traction across the suture line. We have found it useful as a predictor of tension to count by bronchoscopy or by spiral CT reconstruction the actual number of tracheal rings readily available. Crammed tracheal rings usually predict good tracheal elasticity during the operation.

From your study, it clearly appears that tracheostomy is an important risk factor. What are your alternative means to defer operation if the stenosis is not stabilized? Would you recommend laser resection or the use of indwelling stents for this purpose or for the treatment of complications?

Dr Wright. In the end, we believe that preoperative tracheostomy is a surrogate for a complex stenosis case, and it is an additional marker for severity of disease in that diagnosis group. We don't avoid tracheostomy if it is needed. We have not particularly noticed your astute observation in terms of looking at the rings, although I think you are on the right track.

We in general avoid laser treatment. We prefer dilation. It is simpler, it is less costly, and we believe it has fewer side effects. We don't use indwelling, self-expanding metallic stents. We think those often extend a stenosis. We do use silicone stents and prefer T-tubes.

Dr Rendina. We believe that the use of low-dose steroids is beneficial in tracheobronchial reconstruction because it reduces anastomotic edema. In your article, you state that you consider steroids to be hazardous, although I believe you refer to higher doses. Would you please comment?

Dr Wright. We defined high-dose steroids as more than 10 mg/d within a week before the operation, and we have always long held that this was a possible risk factor for an anastomotic problem. Preoperative steroid use was seen in only about 7% of our patients, because we screen out those patients and wean them from steroids. We do think that steroids are not good for an anastomosis and try to avoid them. There are certainly experimental reasons why they might be harmful.

I think what you are really asking is do we use them after the operation, and I would say we never use them for a tracheotracheal anastomosis because there is never a problem with anastomotic edema with that anastomosis. We rarely use them for laryngotracheal anastomoses. For very high anastomoses, when the patients have postoperative trouble with swelling, we use a short course, a day's worth or so, of high-dose steroids.

Dr Rendina. PITS may occur as a consequence of injury to the central nervous system, and these patients may have permanent behavioral or motor damage. Have you considered patients with neurologic damage to be exposed to an increased risk?

Dr Wright. I certainly agree with you that many patients with a closed head injury tug against the endotracheal tube with random movements, which may be a risk factor for postintubation tracheal stenosis. Usually by the time we get them, they are a lot better; either they are normal or else they are calm.

Dr Carlos Saldarriaga *(Medellin, Colombia).* During the last 2 years, the San Vincente Hospital in Medellin, Colombia, has reported on 3 patients with tracheal transplantation. One died on postoperative day 12, but the other 2 are doing well now at 12 and 10 months of follow-up. In your series, almost 35 patients had a permanent tracheostomy. I would like to know your comments and the opinion of your group in Boston about tracheal transplantation.

Dr Wright. That is a good question. We certainly look forward to successful tracheal transplantation. We still think it is years off in terms of being reliable. Another way to look at this is that despite doing a lot of high-risk resections, our results are not all that bad. Even if you get a failure, the risk of death is only 7%, whereas I would have to think that if you did 900 tracheal transplantations that the risk of death would probably far exceed 7%.