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Medical and Social Factors as Predictors of Outcome in Infant Tracheostomy

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Summary

We examined the relative impact of infant tracheostomy in comparison to associated medical and social factors, on developmental outcome as part of a cross-sectional follow-up of 32 children. These children had no mental retardation, physical handicap, or severe neurological problems, but had a history of long-term tracheostomy in infancy, ranging from 3 to 146 months duration.

Medical factors evaluated included prematurity, neurological status, severity of illness, and number of weeks hospitalized. Social factors included parental education and occupation. Outcome measures included IQ, language quotient, growth parameters, and behavioral competence. Correlation analyses, stepwise multiple regression analyses, and t-tests were used.

Early medical illnesses were significant predictors of cognitive, language, and growth outcome. Severity of medical complications at birth and the presence of any neurological problem predicted 49% of the variance in IQ at follow-up. Social class was the only variable to predict behavioral outcome, accounting for 28% of the variance. For children without confounding medical conditions, tracheostomy had a negative impact on overall language and auditory comprehension. Once children with confounding medical risk factors were removed from the sample, children with history of infant tracheostomy exhibited significantly lower overall mean language scores (106 versus 120), and lower mean language comprehension scores (104 versus 119) than a matched comparison group.

Keywords

Prematurity; neurological status; postnatal illness severity; parental education; occupation; IQ; overall language quotient; child behavior checklist correlations; stepwise multiple regressions; t-tests

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INTRODUCTION

Since, due to medical technological advances, many small preterm and other infants now survive early medical illnesses, a trend towards increased incidence and duration of infant tracheostomy has been reported.^{1,2} For example, the mean duration of tracheostomy in one large sample of children doubled over the 10 year period between 1970 and 1980.¹

In agreement with other reports,³⁻⁴ we have previously documented a high prevalence of developmental disabilities in children who sustained tracheostomy of more than one month's duration in the first year of life.⁵ Half of the number of surviving children were found to have mental retardation, cerebral palsy, or other significant disabilities.⁵

Reflecting changes in neonatal intensive care practices, children who currently undergo tracheostomy are more likely to be younger, even less than one year of age,^{1,5} than those cared for previously. In a recent study of a large group of children the average time with tracheostomy in place was 30 months. The longer duration of tracheostomy, in combination with the younger ages of children with tracheostomies, might have negative implications for later developmental outcome, since infancy and the early preschool years are critical periods for the development of language skills.⁵ Even when considering those children without mental retardation or other primary severe developmental disabilities, long-term infant tracheostomy has been associated with later speech difficulties, and behavioral and growth problems.^{5,6} However, it is not clear whether later developmental problems result from the impairment of long-term tracheostomy, per se, or whether they primarily reflect the negative sequelae of medical conditions confounded by tracheostomy. Since tracheostomy in infants is frequently associated with other risk factors known to affect developmental outcome, such as very low birth weight, prematurity, neurological problems, and lower social class, it is important to assess the extent to which these factors contribute to the developmental delays noted in children with history of tracheostomy.⁵

This study addressed two questions: 1) what is the impact of infant tracheostomy on developmental outcome relative to other associated medical and social factors and 2) do infants with a history of long-term tracheostomy, but without other medical and neurological conditions, differ from matched controls in developmental outcome measures?

MATERIALS AND METHODS

Thirty-two children with a history of tracheostomy of at least 3 months duration, initiated before 13 months of age, comprised the study group. They were seen as part of a follow-up study of children who had tracheostomies, from 1972 to 1982, at two large urban pediatric tertiary care hospitals. These children were not mentally retarded (IQ above 70 on standardized testing), and had no severe physical disabilities, neurologic disorders, multiple malformations, or neurosensory abnormalities. A sub-group of seven children, without any medical risk factors other than tracheostomy, were also compared to a control group matched by age, race, sex, and social class. Indications for tracheostomy in this subgroup were congenital or acquired subglottic stenosis, laryngeal web, hemangioma, cyst, and epiglottitis without additional medical illnesses or complications.

Medical and demographic variables documented from chart review included race, sex, social class (parental education level and occupation), based on Hollingshead⁷ and collapsed to a 3 point scale, with three representing the lowest social class group. Also taken were gestational age (GA) based on Dubowitz evaluation, birth weight in grams, and total length of stay (LOS) in number of weeks, in hospital. The presence or absence of central nervous system conditions (CNS) that might affect outcome was specifically noted, including the following: hydrocephalus, seizures, intraventricular hemorrhage, neonatal seizures, apnea requiring a respirator, asphyxia with Apgar scores less than 6 at 10 minutes, and abnormal CT scan. In addition, the Postnatal Complications Scale (PCS)⁸ was used as a more general measure of illness severity. The PCS rates the presence or absence of ten possible early medical conditions, namely, respiratory distress syndrome, mechanical ventilation, surgery, hyperbilirubinemia, infection, anomalies, metabolic disturbance, convulsions, temperature disturbance, and feeding difficulties. Scores ranged from 50 to 150, with highest scores considered optimal.

Outcome measures included the following standardized assessments: intellectual status, through the Bayley Mental Scales of Infant Development,⁹ the McCarthy Scales of Children's Abilities,¹⁰ or the Wechsler Scales for children.¹¹ The Peabody Picture Vocabulary Test¹² was used for children who still had tracheostomy tubes in place. These assessments varied within content domain, dependent on the age of the child. All scales yield standard scores that compare a child's functioning to that of a normative group.

An overall language quotient (LQ) was derived from the results of one of the following tests: the Preschool Language Scale,¹³ the Test of Early Language Development,¹⁴ or the Tests of Language Development—Primary/Intermediate.¹⁵ Because speech difficulties have been identified in previous studies of tracheostomized children, standard scores measuring expressive (verbal ability quotient) and receptive (auditory comprehension quotient) language skills were also used as outcome measures.

For children four years of age or older, the Child Behavior Checklist (CBCL)¹⁶ measured social and behavioral competence via parental report. The scale identifies clusters of behavioral problems that can be compared to normative data from age and sex peers. Total number of t-scores greater than the 98th or less than the 2nd percentiles for behavioral problems or social competence were used in analysis. Weight percentiles for age and sex based on standard National Center for Health Statistics growth grids¹⁷ were obtained as a measure of overall physical growth.

To address the first question about the impact of tracheostomy on developmental outcome relative to other medical and social conditions, correlation analyses and a series of stepwise medical regressions were computed. Outcomes were regressed on medical and social conditions to test the relative predictive ability of these conditions to outcome. Outcomes included IQ, language quotient (LQ), weight percentile for age, and CBCL scores. Stepwise linear multiple regression analyses were used to determine the relative contribution of the medical and social conditions to the outcome measures. Variables were allowed to enter the equation only if the increase in the amount of variance accounted for was significant at least at the 0.05 confidence level. Medical and social conditions with significant bivariate

relationships to outcome were entered into the regression equations. To address the second question, the comparison of healthy full-term tracheostomy children to matched controls, a series of two sample t-tests were conducted.

RESULTS

Subjects were seen for follow-up at a mean $\pm$ SD age of 5.5 ± 2.6 years, ranging from 1.7 to 12.1 years, and had tracheostomies in place for an average of 30.4 ± 31.3 months. Mean $\pm$ SD gestational age of the sample was 35.7 ± 4.9 weeks. Twenty-nine percent were noted to have CNS conditions. The mean PCS score of 91.9 ± 40.6 indicated a range of severity of medical illnesses in the first month of life. Conditions noted included apnea, neonatal seizures, intraventricular hemorrhage, and hydrocephalus. The children were hospitalized for a mean of 22.5 ± 23.6 total weeks, with tracheostomies in place for a mean of 30.4 ± 31.3 months. The group as a whole was of middle social class (2.1 ± 0.6), but ranged across all socioeconomic strata, with 16% professional and upper middle class, 55% middle or working class, and 30% on public assistance. Overall mean IQ was at the lower end of the average range for the group (92.1 ± 14.5). Mean language skills were also in the low normal range, (93.8 ± 19.3). Mean percentile of weight for age was 36.8 ± 27.7 . Thirty percent of the group had weights for age below the 10th percentile. A high incidence of behavioral problems was noted, with 54 percent of the sample scoring in the deviant range.

The first study question related to the relationships between early medical and social factors and outcome, and to the relative importance of medical and social variables in predicting later intellectual, language, behavioral, and growth outcome. Table 1 outlines the zero-order correlations between predictor and outcome variables. Except for duration of tracheostomy, all early medical and social conditions (PCS score, CNS score, LOS, and GA) were reliably related to IQ, indicating that overall severity of medical condition, presence of neurological risk, longer length of hospitalization, and prematurity, were related to lower intellectual competence in children with history of tracheostomy. Longer hospitalization and the presence of neurological risk related to later poorer language competence and growth retardation, as LQ and weight percentile for age at outcome were related to LOS and CNS score. CNS related positively to negative behavioral adjustment, indicating that the presence of a neurological risk condition conferred risk for later behavioral problems. Duration of tracheostomy was unrelated to any outcome measure. All significant medical and social variables were entered into a series of stepwise multiple regression equations as predictor variables, in order to assess the relative importance of these early medical and social factors to the later outcome of children with history of tracheostomy.

Table 2 outlines the results of the multiple regression analyses. Medical illnesses and problems, other than infant tracheostomy, were the best predictors of IQ, LQ, and growth. PCS and CNS, entered on steps one and two, contributed significantly to the stepwise regression, accounting for 50% of the variance in IQ. CNS and LOS also predicted 40% of the variance in LQ. Only hospital LOS entered into the stepwise regression of weight outcome, accounting for 16% of the variance. Socioeconomic status was the only variable to contribute significantly to behavioral outcome, accounting for 28% of the variance.

The second study aim was to assess whether children with history of tracheostomy, but with no other medical or neurological risk conditions, differed from a comparison group on outcome measures. Table 3 illustrates the results of the outcome comparisons of the means for the tracheostomy subgroup and the matched comparison sample. When the seven tracheostomy children without other coexistent medical conditions were compared to an age, race, sex, and social class-matched group on outcomes measures, all outcomes were within normal limits. However, tracheostomy children performed less well on overall language and auditory comprehension measures ($t = 1.77, 1.85; df = 12, P < 0.05$, one-tailed), indicating a negative effect of tracheostomy on language outcome, independent of other medical and social risk variables.

DISCUSSION

Medical and social factors, other than tracheostomy, were the most significant predictors of outcome in this group of moderately ill infants with tracheostomy. Intellectual and language outcomes were predominantly influenced by medical risk factors, reflecting severity of early medical illness and prematurity, and the presence of mild neurological problems. These medical conditions accounted for substantial amounts of the variance (40–49%) in later language and overall cognitive outcome. Severity of medical problems also predicted growth outcome, as length of stay in hospital was the only variable to account for weight percentile for age at outcome. However, although significant, only a relatively small portion of growth outcome was accounted for, indicating that factors other than the medical, social, and neurologic conditions associated with infant tracheostomy had major influence on growth outcome.

Social class was the strongest predictor of behavioral outcome, lower social class being associated with a greater number of behavioral problems. Parental educational and occupation levels reflected environmental factors that exerted the strongest influence on behavioral outcome, accounting for 28% of the variance in outcome. Once these social factors were considered, medical conditions had little added impact on behavioral outcome.

However, for children without additional medical problems, tracheostomy had a negative effect on overall language skill and auditory comprehension. When only children without additional medical illnesses or neurological problems were considered, and when social class, age, and race were controlled, children with a history of long-term tracheostomy still showed weaknesses in overall language and comprehension skills, relative to non-tracheotomized children.

Previous studies have indicated that infants who undergo long-term tracheostomy are likely to be at risk for later developmental problems due to associated medical conditions, such as prematurity, medical illnesses, lengthy hospitalizations, and neurological problems. The present study suggests that, even when severe conditions such as mental retardation and neurological syndromes are excluded, medical conditions of moderate severity, other than tracheostomy, exert significant influence on later developmental outcomes in the areas of intellectual skills, language skills, and growth. Social class was a significant predictor of behavioral outcome, exerting a stronger influence than severity of medical illness or

presence of neurological risk. Nonetheless, since the amount of variance in behavioral outcome, accounted for by all the independent variables, was relatively small, other factors not measured in this study must be considered.

Our findings are consistent with previous studies indicating that early medical illnesses, especially those postnatal complications assessed in this study, and social class, are important predictors of later developmental outcome, even when children with severe disabilities are excluded.^{18–20} However, even when medical illness, mild neurological conditions, and social class were controlled, children with history of tracheostomy performed less well on tasks measuring verbal comprehension and overall language ability, suggesting that tracheostomy itself is associated with later language difficulties independently of other medical or social conditions. The inhibited vocalization and lack of language experience imposed by the tracheostomy appear to be the most compelling reasons for the language skill differences later in life.

Conditions other than the medical illnesses, neurological conditions, and social class differences accounted for in this study, might also be implicated in affecting later differences. These conditions could include clinically significant but non-apparent anoxic or hypoxic episodes before and after tracheostomy. Mild hearing deficits, not measured in this sample, may also be responsible for specific language disabilities. Another weakness of the current study is the relatively small sample size. With multiple group comparisons made in examining differences between children with tracheostomy and controls, the chances of Type 1 error are increased. Although the present study encompasses the largest follow-up of tracheotomized children to date, our research indicates that infant tracheostomy is most likely to occur in the context of multiple additional risk conditions, which also affect outcome. The retrospective collection of medical information may negatively affect reliability of those measures. Outcome measurements were also collected cross-sectionally. Some delays noted in children in the present study may resolve with older age. However, our previous work, indicates that language deficits are more likely to become apparent with older age.⁶ Prospective studies using multiple sites, experimental designs, and larger populations to control for confounding variables are necessary to understand fully the specific developmental sequelae of infant tracheostomy.

Current knowledge indicates that, of children who undergo tracheostomy, those with greater severity of early associated medical illnesses will have significantly increased risk of intellectual, language, and growth problems. However, even when other medical and neurological risk factors are held constant, children with a history of long-term tracheostomy in infancy remain at increased risk for specific language problems. Pediatric pulmonologists and other pediatricians working with children with tracheostomy should be aware of the increased risks for language problems in this group and should make appropriate referrals for intervention when necessary.

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TABLE 1

Significant Correlations Between Predictor and Outcome Variables

Predictor variable	IQ	LQ	Weight	CBCL
PCS	0.57 ***			
CNS	-0.47 **	-0.49 **	-0.31 *	0.40 *
SES	-0.25 *			0.54 ***
GA	0.33 *			
LOS	-0.44 **	-0.65 ***	-0.44 *	

PCS, postnatal complications scale score; CNS, presence of neurological risk; SES, socioeconomic status; GA, gestational age; LOS, total weeks hospitalized; LQ, language quotient; CBCL, child behavior checklist.

* $P < 0.05$

** $P < 0.005$

*** $P < 0.001$

TABLE 2

Results of Stepwise Regressions on Outcome Measures (N = 32)^a

Outcome Measure					
IQ					
Step 1	R	R ²	Adj R ²	Sig F	R ² ch
	0.60	0.36	0.34	0.000	0.36
	Predictor		Beta In	r	
	PCS		0.59	0.59	
Step 2	R	R ²	Adj R ²	Sig F	R ² ch
	0.70	0.49	0.46	0.000	0.14
	Predictor		Beta In	r	
	CNS		0.39	0.53	
Language quotient (LQ)					
Step 1	R	R ²	Adj R ²	Sig F	R ² ch
	0.54	0.29	0.27	0.003	0.29
	Predictor		Beta In	r	
	CNS		-0.54	0.54	
Step 2	R	R ²	Adj R ²	Sig F	R ² ch
	0.64	0.41	0.36	0.002	0.11
	Predictor		Beta In	r	
	LOS		-0.34	-0.43	
Weight percentile for age					
Step 1	R	R ²	Adj R ²	Sig F	R ² ch
	0.40	0.16	0.13	0.02	0.16
	Predictor		Beta In	r	
	LOS		-0.39	-0.39	
Behavioral outcome (CBCL)					
Step 1	R	R ²	Adj R ²	Sig F	R ² ch
	0.53	0.28	0.25	0.002	0.28
	Predictor		Beta In	r	
	SES		0.53	0.53	

^aFor abbreviations, see Table 1 footnotes.

TABLE 3
Comparison of Means $\pm$ SD of Outcome Measures (N = 7)

Between Tracheostomy and Control Children

Measure	Tracheostomy	Controls	t	P
IQ	102 $\pm$ 14	114 $\pm$ 16	1.51	N.S.
Language quotient	106 $\pm$ 16	120 $\pm$ 12	1.77	<0.05
Auditory comprehension quotient	104 $\pm$ 14	119 $\pm$ 15	1.85	<0.05
Verbal ability quotient	109 $\pm$ 20	120 $\pm$ 10	1.23	N.S.
Weight percentile for age	49 $\pm$ 36	54 $\pm$ 25	.48	N.S.