THE COMPLICATIONS OF ENDOTRACHEAL ANAESTHESIA*

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GILLIES points out that of all the technical improvements designed to make inhalation anaesthetics safer, simpler, and more efficient, tracheal intubation is one of the most notable (1). Its advantages were recognized by Trendelenburg, McEwen and others, who realized the need for an unimpeded channel for anaesthetic vapours and oxygen, and simultaneous protection of the unconscious patient against aspiration of blood and debris during operations on the mouth and pharynx. Need for a near perfect airway has become even more important since the introduction of methods involving generalized muscular paralysis, where ventilation has to be maintained by the anaesthetist. Surgeons and anaesthetists know that accidents occasionally occur in the performance of difficult techniques. These reports should not discourage us from an undeniably useful procedure, but should help us avoid some of these complications. The discussion today concerns itself with these complications.

Trauma during intubation is a fairly common occurrence; it is more frequently associated with the inexperienced anaesthetist (2). Insertion of a laryngoscope may result in lacerated lips, abraded gums, loosening, fracture or extraction of teeth, abrasions and lacerations of the hard and soft palate and the posterior wall of the pharynx, and damage to the tongue. Insertion of a tube through a nostril may cause nasal mucosal abrasions, especially in the region of the turbinates and anterior septum, with resultant epistaxis (3, 4). A nasal polyp may be traumatized, or even avulsed with resultant bleeding.

During intubation the supraglottic, glottic, or infraglottic structures may be injured. These may be soft tissue injuries, or cartilage and perichondrial injuries. The soft tissues of the membranous glottis may sustain minimal abrasion or crushing. Recovery is usually prompt. A puncture injury of mucosal and sub-mucosal tissue may result in ecchymosis, hematoma, or even emphysema. Excoriated areas may become infected and covered with an exudate, which can lead to formation of a granuloma. More extensive trauma to the membranous glottis may be a laceration, or even avulsion of a cord. Forward elevation of pharyngeal structures during intubation causes a stretch, resulting in transient pharyngeal discomfort.

The most common reaction following intubation, usually seen in the first 24 to 72 hours, consists of loss of lustre, slight rounding, and pinkish infiltrations of the vocal lips of the true cords. Trauma of a more severe degree, or even minimal trauma with added infection, may result in marked inflammation and acute laryngeal obstruction.

Cartilage and perichondrial injuries may involve the epiglottis, thyroid, aryte-

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noid or cricoid cartilage, or the crico-arytenoid articulation. Inflammation of the lingual surface of the epiglottis may cause oedema, or even abscess formation. The swelling does not spread onto the laryngeal surface, as the mucous membrane there is tightly adherent.

The reparative process for cartilage in the larynx is very poor. If cartilage and its perichondrium are injured, perichondritis, prolonged suppuration, and cartilaginous necrosis with scarring and deformity result. Laryngeal stenosis ensues if remedial measures are not taken to prevent it. In general, most intra and extra laryngeal damage fortunately consists of slight mucosal engorgement, with little if any subjective complaints, or functional disturbances. In many cases of sore throat there is little or no evidence of trauma. Conversely, positive evidence of trauma does not always produce symptoms. Wylie says that in view of the vast number of intubations, laryngitis is relatively uncommon (5).

Acute oedema of the glottis may follow intubation (8). It is more common in infants than in older children or adults. Crispell and L. J. Hampton in reviewing 337 children receiving endotracheal anaesthesia over a 18-month period, beginning October 1947, at the Grace New Haven Community Hospital, reported that there were two cases requiring tracheotomy for laryngeal oedema (6). In those two cases the cerebellar head rest had been used. Mild degrees of laryngeal dysfunction with hoarseness were fairly common. Shaw reports a case where a 25-year-old burned negro patient, who had had a difficult induction and intubation, and four and one half hours of skin grafting with the head in a cerebellar rest, became completely obstructed on extubation, so that tracheotomy was necessary. They were unable to re-insert the tube as the cords were not visualized, and the aryepiglottic folds were seen to be a pinkish mass of oedematous tissue (7). In most of the cases of severe oedema reported, it appeared that induction and intubation were usually lengthy and difficult.

Gillespie attributes laryngeal oedema to a streptococcal infection, which gains entrance into a mucosal abrasion at the time of operation (8). Mechanical irritation plays a role. Elevation of a cranial bone flap, for instance, necessitates a considerable movement of the head and neck, with possible irritation of structures adjacent to the larynx. As to etiology of tracheal and laryngeal oedema in children, R. M. Smith mentions the following causative factors: oversized tubes and laryngoscopes, intubation during light anaesthesia and spasm, unstable apparatus dragging on the tube, a tugging respiration see-sawing the tube back and forth across the cords, high flows of unhumidified oxygen, and the improper cleansing and storage of tubes, scopes, and catheters (9). Deming, in reporting on anaesthesia for 49 cases of tracheo-oesophageal fistula in the newborn, and on 250 other intubations of patients under fourteen days old, had no cases of obstruction from laryngeal oedema. All these patients were placed in an isolette with humidified oxygen after operation. She believes that absolute cleanliness of tubes together with correct size, and atraumatic intubations, are the most important factors in avoiding laryngeal oedema (10).

Many cases of laryngeal granulomata following intubation have been reported. Gillespie states that these may follow use of many types of tubes, even of the softest variety, and may ensue after either nasal or oral intubation (8).

Young and his colleagues at the Manchester Royal Infirmary recently report an interesting series of twelve cases seen in three years of routine E.N.T. practice (11).

A few days after the anaesthetic, the appearance is that of an acute laryngitis, but when this general inflammation subsides, a small area of ulceration may be seen at the glottis, usually on the vocal process of one or both arytenoid cartilages. Granulations may proliferate at the ulcer site, and may organize to form polyps, or a pedunculated fibroma in the course of time. Apparently a similar nodule may form as a submucosal hematoma. Grossly these lesions vary in size, shape, and position. In most of their cases, the polyps appeared on the posterior one-third of the cords. Not infrequently the site is in the interarytenoid area, just below the glottis. In either case there is a tendency to web formation later. The microscopic picture usually shows a small nodule with thickened epithelium, superficial ulceration, and subepithelial haemorrhage.

Some cases are symptomless, and would only be picked up on routine laryngoscopy. The commonest symptoms encountered were hoarseness, intermittent loss of voice, dyspnoea, pain or discomfort in the throat, rarely haemoptysis in the first few weeks, later there may be a sensation of something moving in the throat if a pedunculated polyp is present. The condition is essentially one of adults. Acute oedema of the larynx in children seems to be the corresponding effect of the lax tissues of childhood. Granulomatous lesions are more frequent in women than in men.

Etiology includes injury on passing the tube and movement between the tube and cords. Pressure by the tube is considered important by Dwyer and his colleagues, in causing tracheitis and granulomas (12). They demonstrated that the curve of the tube may force it into the back of the glottis, and at the same time against the front of the trachea. They suggested a double curved tube, so moulded as to fit as nearly as possible into the contour of the pharynx, larynx, and trachea, when the head and neck are in normal relationship to each other. Young *et al* could show no relationship between these lesions and the materials of which the tube is made, or between them and any particular antiseptic or lubricant used (11).

Regarding prevention, these authors stress gentle respiration, when the tube is passed, afterwards, and until it is withdrawn. Dwyer *et al* say that raising and flexing the head lessens the curve the tube must take at the larynx, and hence lessens the pressure thereon. Lowering and extending the head increases the angle of the tube at the cords, and hence the pressure. On the other hand R. T. Barton advises that one should avoid a sharply flexed head position, and strive for hyperextension (13).

Young *et al*. say that if an ulcer occurs, complete voice rest will help it to heal without formation of excessive granulation tissue. There is a tendency for nodules to disappear naturally, and removal should be postponed until it is apparent that this is not going to take place. Symptoms may eventually dictate the need for excision, simple snaring or punching out by direct laryngoscopy being sufficient. However, the operation may have to be repeated, and this should be done before too much time elapses.

A pathological entity termed "subglottic membrane" has been reported by

Etsten and Mohler (14), Baron and Kohlmoos (15), Snyder and Gants (16), and Muir and Stratton more recently (17). Etsten and Mohler had three cases out of eight hundred adult intubations. These three developed acute upper respiratory obstruction 24 to 48 hours after anaesthesia. Clinically there was cough, dyspnoea, and suprasternal retraction. On direct laryngoscopy, the glottis, epiglottis, and larynx appeared normal, and there was no laryngeal oedema. Bronchoscopy revealed an adherent subglottic membrane. This could have been missed if a tracheotomy had been done to relieve obstruction before an accurate diagnosis was made. Etsten's three cases, all were women with short fat necks. Magill tubes with cuffs, inserted with a stylet, were used. The tubes all fitted snugly, and the cuffs were therefore not inflated. A sense of resistance was encountered during extubation.

The subglottic area is the narrowest portion of the larynx, completely surrounded by the cricoid cartilage with mucosa attached. This area is very prone to injury with subsequent infection. A slight narrowing of the lumen here easily results in obstruction. The mucosa may be damaged by the tip of the tube, the point of a stylet, or by prolonged pressure of a deflated or wrinkled cuff. The use of a small smooth cuff on a tube properly sized, with the cuff placed entirely below the cricothyroid mucosa, eliminates this factor.

After injury to the subglottic mucosa, leukoplakia and desquamated epithelial cells accumulate about the abraded area, and a fibrinous exudate forms, adhering to the anterior wall of the cricothyroid membrane. The medial aspect of this formed membrane, when free, comes in contact with the inferior surface of the vocal cords causing obstruction.

Differential diagnosis of obstruction can be greatly aided by direct laryngoscopy. Laryngeal oedema, granuloma of the vocal cord, or a foreign body can be seen by this procedure. If the glottic and supraglottic areas appear normal, bronchoscopy may reveal a subglottic membrane, slough of bronchial mucosa, or necrotic tracheitis. Treatment of subglottic membrane is immediate removal by bronchoscopy. If the entire membrane is not removed it may recur in 24 hours.

Tracheitis is a definite entity associated with retrosternal soreness, and usually some cough (5). F. L. Turner has described three cases of slough of tracheal mucosa. This may cause respiratory obstruction within 24-48 hours, characterized by a high-pitched wheeze. The obstructive signs appear mainly in the expiratory phase of the respiratory cycle (18).

Necrotic tracheitis is a rare and terrible complication. Ransom describes a case where a 37-year-old woman had a myomectomy under a pentothal, cyclopropane ether anaesthetic, using a #7 Magill tube (19). Next day the patient became dyspnoeic, with some stridor and production of green sputum. On the third day tracheotomy was performed with great difficulty but the patient died on the table. Necropsy showed the larynx and trachea smaller than normal, with a subchronic inflammation in the trachea and bronchi, with superimposed acute changes in the trachea, bronchi, and lungs. The tube was made of war-time rubber, and had been soaked in 1:1000 biniodide of mercury. Patch tests on volunteers using various combinations of rubber, cotton, and solution seemed to incriminate the mercury solution, and thereafter no tubes were soaked in it.

The major postoperative respiratory complications include pneumonia, acute

bronchitis, empyema, lung abscess, and atelectasis (8). Almost all are infective. These are held responsible for a large number of post-operative deaths. They are especially common with patients in poor physical condition. Bronchopneumonia is a common post-mortem finding in all elderly patients. It is equally common in patients who die after operations. In the latter case, the complication was previously labelled "ether pneumonia." It is now believed that the pulmonary lesion is only indirectly attributable to the effects of the anaesthetic, and that the type of operation performed, and the condition of the patient, are important causative factors. Campbell and Gordon surveyed postoperative complications in 2094 unselected anaesthetics, and found that the incidence of complications was less in the group who were intubated (20). They concluded that this was probably owing "to the exclusion from the trachea of infection, and secondly to the opportunity presented to the anaesthetist for removing mucus from the trachea by suction through the tube." There is, of course, a possibility of introducing infection from the nose, and many spirited articles have been written regarding this possibility. One surgeon was quoted as describing nasal intubation as a "perfectly filthy method." It is probably the feeling of most modern anaesthetists that unless there is a definite indication for nasal intubation, the oral route is to be preferred.

Cardiac arrhythmias often appear during intubation and extubation. Burstein has reported on this complication, attributing them to insufficient depth of anaesthesia, prolonged laryngoscopy, respiratory obstruction, and irritation of the tube. In another article he points out that most of the arrhythmias are transient, and of no grave importance (21, 22).

Finally, mention will be made of the rarer complications. Wylie reports a case as follows (5). An 18-year-old boy developed a laryngospasm on induction. This was finally controlled, he was intubated, and the pharynx packed. At that time some engorgement of the larynx and pharynx was noted. In ten minutes there was fluid in the tracheal tube. This was sucked out. After operation, he was extubated, but laryngospasms and cyanosis recurred. A diagnosis of acute pulmonary oedema was made, an orotracheal tube was again passed, and much pink frothy fluid aspirated. During the next 45 minutes his condition deteriorated in spite of cardiac stimulants and oxygen, and he succumbed. Post-mortem examination showed the lungs were solid with haemorrhagic fluid, with uniform oedema throughout. The heart showed a dilated right ventricle. The meninges, brain, and liver were engorged.

Barnard reports an unusual incident during nasal intubation. When the tube reached the laryngeal region, a sudden resilient resistance was felt. On direct laryngoscopy it was noted that the tube was covered with pharyngeal mucosa. He had entered the submucosa in the nasopharynx, and had passed the tube down under it (4).

Finer reports a case where an unsuspected mucous cyst of the right arytenoid process of the larynx caused no obstruction until after pentothal and curare were given. This resulted in such distortion that it was not possible to intubate until muscle tonus had returned. Some oxygen was finally forced in when the patient's head was turned to the right. Thus it must be recognized that distortion of

anatomical relationships by anaesthesia may precipitate a mechanical obstruction in a patient who otherwise can maintain a patent airway while awake (23).

Impaction of the epiglottis has been reported (24). In this case when the second plane of surgical anaesthesia was attained, obstruction accompanied by a strange flapping noise occurred. On laryngoscopy it was noted that an overhanging epiglottis had been sucked down between the cords, causing a valve type obstruction. Intubation remedied the trouble.

It cannot be too strongly emphasized that insertion of an endotracheal tube with too small a diameter may cause obstruction, especially in children and infants. An aged tube may kink in the region of the pharynx. R. W. Shaw points out that a tube may become solidly plugged with blood or secretions causing the very thing it was meant to prevent (25).

Cuffs on tubes may cause obstruction. Too thick a cuff will require so much pressure for inflation, that a Magill tube may be collapsed by it. Too thin a cuff may bulge out in front of the tube, especially if over-inflated, causing a condition resembling bronchospasm. The remedy is to release the cuff (8). Loss of a cuff from a tube may occur. Lennon and Rovenstine reported a case in which death followed the rupture of an inflatable cuff inside a trachea which was already damaged (26). The patient developed subcutaneous emphysema, and died on the second day after operation. Autopsy showed a break in the mucosa of the right main bronchus, in an area of long standing ulceration. This accident was due to two rare phenomena, rupture of a cuff and ulceration of a bronchus.

We are all familiar with the possibility of intubating the right main bronchus and the trouble it may cause. Bishop reports a case in which an 11-month-old infant was intubated for cheiloplasty using a makeshift tube cut from a #16 French catheter (27). Almost immediately respirations ceased. Inflation of the lungs was attempted. Death ensued in one or two minutes in spite of resuscitative efforts. At necropsy, the respiratory tract was removed in one piece. It became apparent that the tube was placed down the right main bronchus, at the same time shutting off the bronchial division of the left lung, and a portion of the divisions of the right lung. It had not been appreciated that an infant's trachea is only 4 cm. long. Leigh and Belton claim that this difficulty is further enhanced since children are diaphragmatic breathers, and this causes a slight ascent and descent of the trachea on inspiration and expiration (28).

There are, of course, many dangers associated with using compressed gases in endotracheal anaesthesia. The pressure in a full cylinder varies from 2000 lb. to the square inch in the case of oxygen, to 75 lb. for cyclopropane. If by some accident such pressures are brought to bear on the patient's respiratory tract, grave damage will ensue. Even reducing valves may be set up to 80 lb. per square inch. The danger to the patient of an accidental release of a gas is greater when endotracheal anaesthesia is in use. Experimentally, Marcotte *et al.* have shown that an intrabronchial pressure of 24 mm. Hg. produced mediastinal emphysema in dogs (29). The danger of causing emphysema, or even rupture of the lungs in a human, is obvious. Needless to say, if an explosion occurs, the danger to the patient is greatly enhanced if he is intubated, and is on a closed or semi-closed system.

Loss of a tube below the cords may occur. Paralysis of the vocal cords following endotracheal anaesthesia is in most instances due to inadvertent section of the recurrent laryngeal nerves. Trauma to the carina has been reported, as well as tracheal webs, leucocytic membrane of the end of the trachea, and perforation of the trachea. Tubes have been inadvertently passed into the stomach, and that viscus ruptured by being forcibly filled with oxygen or gas. Rupture of an aortic aneurysm is considered to be a possibility during intubation, although I have not read of such an accident occurring.

SUMMARY AND CONCLUSION

I have attempted to deal with the complications of endotracheal anaesthesia, stressing some and of necessity dealing briefly with others. These sequelae include injuries and infections of the supraglottic, glottic, and infraglottic areas. Special mention has been given to such entities as laryngeal oedema, laryngeal granuloma, subglottic membrane, and laryngotracheitis. The more unusual complications connected chiefly with mechanical difficulties have been considered. In most instances recommendations for their prevention or treatment have been outlined.

In spite of these complications, the merits of endotracheal anaesthesia stand established at the present time. Sometimes undesirable features are associated with its management, and, unfortunately, these always accrue to the patient. Careful discrimination in regard to the selection of the technique, and meticulous management when it is chosen, are essential safeguards in its application.

RÉSUMÉ

Parmi tous les perfectionnements techniques destinés à rendre l'anesthésie par inhalation plus sûre, moins compliquée et plus efficace, l'intubation endotrachéale est l'un des plus importants (1). On lui reconnaît les avantages suivants: elle procure une voie libre pour les vapeurs anesthésiques et l'oxygène en même temps qu'elle protège le patient inconscient contre l'aspiration de sang et de débris au cours des interventions sur la bouche et le pharynx. Des accidents surviennent quelquefois au cours de manipulations présentant des difficultés techniques. Leur éventualité ne doit pas nous empêcher cependant de pratiquer cette technique d'une utilité indéniable mais elle devrait nous aider à éviter quelques-unes de ces complications.

Au nombre des traumatismes pouvant survenir au cours de l'intubation, on peut mentionner des coupures aux lèvres, des éraflures aux gencives, des lésions aux dents ou à la langue, des éraflures et lacérations au palais dur ou mou ainsi qu'à la paroi postérieure du pharynx. L'intubation nasale peut causer des éraflures à la muqueuse ou l'arrachement d'un polype avec épistaxis consécutif. Les structures supraglottiques, glottiques ou infraglottiques peuvent subir des lésions susceptibles d'entraîner par la suite la formation d'ecchymoses, d'hématome, d'emphysème ou d'un granulome. L'arrachement d'une corde vocale peut se produire. Une sténose de la glotte peut survenir par nécrose post-traumatique d'un cartilage et infection consécutive.

Dans plusieurs cas de maux de gorge à la suite d'intubation, on ne retrouve

que peu ou pas d'évidence de traumatisme, et, par contre, le traumatisme ne produit pas toujours des symptômes.

L'intubation peut être suivie d'un œdème laryngé, de granulomes ou de polypes du larynx. Ces troubles seraient causés soit par le traumatisme à l'introduction du tube, soit par les mouvements des cordes vocales sur le tube. On rapporte de l'obstruction respiratoire aigue à la suite du développement d'une membrane sous-glottique après intubation (14, 15, 16, 17).

Une trachéite peut se développer et causer de l'obstruction respiratoire en dedans de 24-48 heures. Une trachéite nécrosante est une complication rare mais terrible (19).

Des arythmies cardiaques se produisent souvent durant l'intubation ou à l'extubation. La plupart de ces arythmies sont transitoires et d'aucune gravité; on les attribue soit à un niveau d'anesthésie trop léger, soit à une laryngoscopie prolongée, ou à de l'obstruction respiratoire ou à l'irritation causée par le tube (21, 22).

L'auteur discute aussi des facteurs mécaniques qui peuvent produire une obstruction respiratoire durant l'anesthésie endotrachéale.

En dépit de ces complications, les avantages de l'anesthésie endotrachéale demeurent bien établis à l'heure actuelle. Son emploi s'accompagne de temps en temps d'effets indésirables et malheureusement ils sont toujours au détriment du malade. Il faut user de discernement dans le choix de la technique et, quand le choix est fait, ne faire que des manipulations de toute délicatesse: voilà les gages de sécurité de son emploi.

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