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Radiologic Localization of the Laryngeal Mask Airway in Children

Nishan G. Goudsouzian, M.D., William Denman, F.C.Anaes.,† Robert Cleveland, M.D.,‡ George Shorten, F.F.A.R.C.S.(I.)†*

In the absence of data on the anatomic localization of the cuff of the laryngeal mask airway (LMA) in children, radiologic images were obtained from 50 infants and children (aged 1 month to 15 yr) undergoing diagnostic radiologic procedures during halothane and N_2O:O_2 anesthesia. In 46 patients, the cuff of the LMA was in the pharynx and covered the laryngeal opening. The upper (proximal) section was adjacent to the base of the tongue at the level of C1 or C2 vertebrae pushing the tongue forward and its lower (distal) end was in the inferior recesses of the hypopharynx at the levels of C4 to T1 vertebrae. The cuff of LMA at this position between the base of the tongue above the epiglottis and below the laryngeal opening, covered the laryngeal aperture, forming a low pressure seal at the entrance of the larynx. In 37 of these 46 patients, a posterior deflection of the epiglottis was noted (<45°), and in only 9, the epiglottis was in the anatomic position. In four patients, the cuff of the LMA was located in the oropharynx. No correlation was found between the size of the LMA and the position of the epiglottis with respect to end-tidal CO_2, respiratory rate, or the leak pressures. The size of the LMA, its anatomic location, and the position of the epiglottis had no significant effect on the respiratory parameters of spontaneously breathing children. (Key words: Anesthesia, pediatric. Equipment: laryngeal mask. Radiologic diagnostic procedures: computed tomography, magnetic resonance imaging. Radiologic localization: laryngeal mask.)

THE LARYNGEAL MASK airway (LMA) is a tubular oropharyngeal airway that has at the distal end a sealed silicone inflatable cuff. The rim of the cuff provides a low-pressure seal around the perimeter of the laryngeal inlet, through which the patient can continue breathing spontaneously.[1–3] Since there are no data in the literature describing the position of the cuff of the LMA relative to pharyngeal and cervical structures in children, we obtained and analyzed radiologic images of the lateral computed tomography (CT) or magnetic resonance imaging (MRI) scan of the head and neck to ascertain position of the cuff of the LMA relative to anatomic structures. In particular, we wanted to elucidate further how the LMA maintains the airway and to see whether the large cuff distorts the anatomy of the pharynx. This information is important because airway anatomy differs in infants, children, and adults and, whereas the devices for adults were designed based on anatomic studies, the standard pediatric size 1 and 2 LMAs are scaled-down versions of the adult mask.[4]

Methods

The protocol of this study was approved by the Human Studies Committee of our institution, and written informed consent was obtained from parents or guardians; where appropriate, the procedures were discussed with the patients themselves.

Fifty children presenting for MRI or CT scans on the head and neck were evaluated. Anesthesia was induced in the radiologic suite *via* face mask with a halothane N_2O:O_2 mixture. Hemoglobin oxygen saturation (Sp_{O_2}) and blood pressure were monitored and a standard intravenous infusion was started. Once a satisfactory (surgical) level of anesthesia was achieved, the LMA was inserted. The patients were allowed to breathe spontaneously throughout the procedures *via* the LMA. Anesthesia was generally maintained using 1% halothane and N_2O:O_2 in a 2:1 ratio. The inspired O_2, end-tidal CO_2, end-tidal halothane, and respiratory rate were measured by Datex® gas analyzer (Intavent, Amsterdam) *via* a 15-m sampling tube connected to the LMA.

The manufacturer's guidelines were followed to determine the appropriate LMA size. Occasionally, when the weight of the patient did not correlate with his or her anatomic development (as in an overweight infant or one with a congenital anomaly), we substituted masks to obtain the best fit.

Before insertion of the LMA, its cuff was inflated to check for air leak and then deflated. The posterior aspect of the cuff was lubricated with surgical lubricant and lidocaine jelly (4%) and the mask was inserted by an anesthesiology resident in the presence of the attending physician. The LMA was held with the aperture facing anteriorly and passed without visualization into the pharynx with a smooth movement until resistance was felt; at this point, patency of the airway was checked by listening for air entry through the LMA tube. If insertion of the LMA was deemed satisfactory, the cuff was inflated, (during inflation of the cuff, a slight extrusion of the LMA from the mouth was noted). Minor adjustments were sometimes

* Associate Professor of Anaesthesia, Harvard Medical School at the Massachusetts General Hospital.

† Clinical and Research Fellow, Department of Anaesthesia, Massachusetts General Hospital.

‡ Associate Professor of Radiology, Harvard Medical School at the Massachusetts General Hospital. Current position: Children's Hospital, Boston, Massachusetts.

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Address reprint requests to Dr. Goudsouzian: Department of Anesthesia, Massachusetts General Hospital, Boston, MA 02114.

required, such as adjusting the volume in the cuff or rotating it a few degrees. The anesthetic T-piece with the additional side port for gas sampling was then attached. Lung inflation was verified and ventilation was checked by auscultation, observation of the movement of the reservoir bag, and the capnometer. Adequacy of oxygenation was confirmed by pulse oximetry. The adequacy of the seal at the pharynx was tested by applying positive pressure at the reservoir bag while observing the dial of the pressure gauge of the anesthesia circuit. Lung inflation was verified and the pressure at which an audible leak occurred was documented.

In the event the resident was unable to insert the LMA, or if its position was deemed unsatisfactory, a subsequent attempt at insertion was made by the attending anesthesiologist. If the latter was unable to insert the LMA easily, a laryngoscope was used to lift anteriorly the posterior aspect of the tongue and the LMA was inserted into the pharynx.

A copy of the T1 weighted MRI spin echo images in a sagittal plane through the midline of the head and neck was used to ascertain the position of the cuff of the LMA relative to the cervical spine and the natural airway of the patient. With the CT scan, the sagittal reconstructed image of the head and neck was used. All radiologic scans were reviewed by a pediatric radiologist.

Means, standard deviations, and standard errors were calculated by using standard methodology. ANOVA was used to compare the groups on respiratory parameters, for which groups were determined by the position of LMA.

Results

Fifty infants and children aged 1 month to 15 years presenting for CT (n = 7) or MRI (n = 43) were evaluated. The demographic data, the size of the LMA used and the number of attempts required to insert the LMA are summarized in table 1. In 39 children, the LMA could be inserted by the resident-in-training on the first attempt. In nine, the initial attempt by the resident proved unsuccessful and the attending anesthesiologist intervened. In these cases the device could be properly placed after simple manipulation of the patient's airway as by opening the mouth wider, lifting the jaw, and rotating the LMA. In three patients, even these manipulations failed; a laryngoscope was used as a means of lifting the tongue forward and aiding in insertion.

In the patients studied, an audible leak after cuff inflation could be detected at circuit pressures of 8–42 cm of water. The circuit pressure for detecting an audible leak did not differ significantly between the three groups, nor was there any difference in respiratory rates or CO_2 concentration (table 2).

During the procedure, Sp_{O_2} was >97% in all but one patient while spontaneously breathing 50–67% N_2O:O_2 and 1% halothane. The exception was a child who had an upper respiratory infection 1 week earlier. Following insertion of the LMA and while breathing 67% N_2O:33% O_2, the Sp_{O_2} was 91%. The inspired O_2 concentration was increased to 60% and several positive pressure breaths were administered through the LMA. Subsequently, the Sp_{O_2} stabilized at 97%.

TABLE 1. Demographic Data of the Patients According to the Size of LMA and the Number of Attempts Required for Insertion

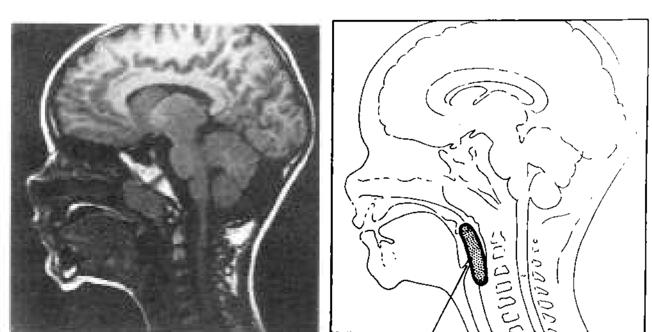
Size of LMA	Age (yr)	Weight (kg)	No. of Attempts (%)
1 (n = 7)	0.4 ± 0.3 (0.1–0.8)	6.7 ± 2.1 (3.7–9)	7 (100%) 1 attempt
2 (n = 35)	2.6 ± 1.7 (1–6)	13.9 ± 4.7 (8.5–27)	25 (71%) 1 attempt 8 (24%) 2 attempts 2 (6%) 3 attempts
3 (n = 8)	10.9 ± 3.9 (4–15)	43.9 ± 13.5 (27–62)	7 (88%) 1 attempt 1 (12%) 2 attempts

The data are mean ± SD, with range in parentheses.

TABLE 2. The Pressure to Detect an Air Leak after the Insertion of the LMA, the End-tidal CO_2, and the Respiratory Rates in the Children Studied

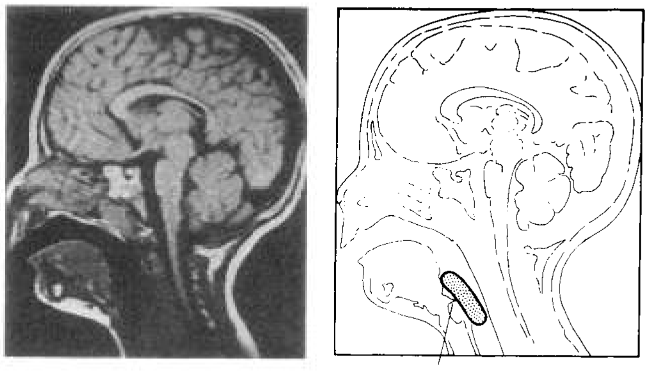
Size of LMA	Leak Pressure (cmH_2O)	End-tidal CO_2 (mmHg)		Respiratory Rate (breaths/min)	
		Mean	Maximum	Mean	Maximum
1	17 ± 3 (8–28)	37 ± 3 (25–48)	39 ± 3 (25–52)	40 ± 4 (25–50)	44 ± 5 (26–55)
2	20 ± 1 (9–42)	42 ± 1 (28–51)	45 ± 1 (33–58)	33 ± 1 (23–46)	38 ± 1 (28–54)
3	22 ± 1 (16–28)	45 ± 3 (30–55)	47 ± 3 (32–55)	32 ± 3 (16–43)	36 ± 3 (19–50)

The data are mean ± SE, with range in parentheses.



EPIGLOTTIS ANATOMIC

FIG. 1. The upper portion of the cuff of the LMA is adjacent to the soft palate superiorly, and the base of the tongue anteriorly at the level of the odontoid process of C2. The lower portion of the cuff is at the level of the pyriform fossae opposite to the C3–4 interspace. The larynx is thus covered by the LMA. The epiglottis is in anatomic position.



EPIGLOTTIS 90°

FIG. 2. The upper section of the cuff of LMA indents the base of the tongue and is opposite the body of C2. Inferiorly, the cuff is opposite to C5. The epiglottis is perpendicular to a line parallel to the anterior aspects of the cervical vertebrae.

TABLE 3. The Anatomic Position of the Cuff of the LMA and the Epiglottis

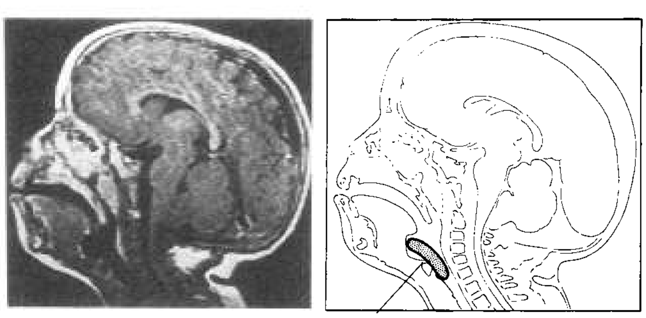
Size of LMA	Upper End of Cuff	Lower End of Cuff	Position of Epiglottis
1 (n = 7)	C2 100%	C4 14%	1 (14%) <90°
		C5 14%	5 (72%) 90°
		C6 57%	1 (14%) >90°
		C7 14%	
2 (n = 35)	C1 23%	Oropharynx 11%	4 Oropharynx 11%
	C2 77%	C4 9%	6 (17%) <90°
		C5 29%	23 (66%) 90°
		C6 26%	2 (10%) >90°
		C7 23%	
		T1 3%	
3 (n = 8)	C2 100%	C5 25%	2 (25%) <90°
		C6 25%	5 (62%) 90°
		C7 37%	1 (12%) >90°
		T1 12%	

The epiglottic angle was determined relative to a line drawn parallel to the anterior aspect of the cervical vertebral bodies.

Radiologic images demonstrated that in 46 patients (92%) the cuff of the LMA was in the pharynx with the upper (proximal) rim of the cuff placed adjacent to the base of the tongue inferior to the posterior aspect of the soft palate (figs. 1–3). The lower (distal) end of the cuff reached to the inferior recesses of the hypopharynx, often posterior to the level of the vocal cords (table 3). In this position the upper transverse section of the LMA cuff pushed the tongue forward, producing a concave indentation of the base of the tongue. Because the cuff extended along the base of the tongue above the epiglottis and below the laryngeal opening (as defined by the epiglottis, aryepiglottic folds, and postinferiorly, the cricoid cartilage), it was thought to cover the laryngeal opening. In these 46 patients, the proximal end of the cuff had a constant location opposite the C1 or C2 vertebra, whereas the position of the lower end was variable from the C4 to the T1 vertebra (table 3).

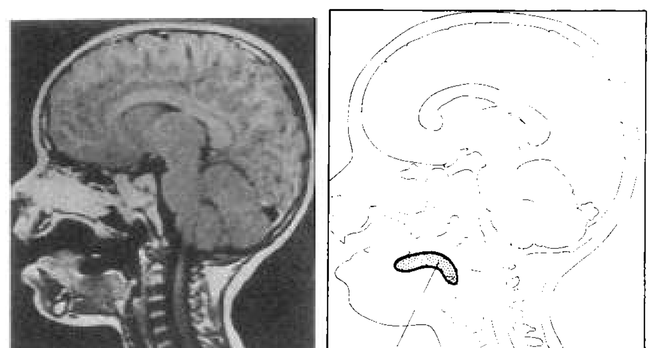
In the four remaining patients (all of whom were in the size 2 LMA group), the LMA cuff was in the oropharynx (fig. 4); despite this position, the children could breathe satisfactorily as evidenced by adequate oxygenation and normal end-tidal CO_2 (table 4). In these four patients, the upper end of the cuff was at the level of the C1 vertebra.

A posterior deflection of the epiglottis (90° or more) was present in 37 (74%) of the infants and children evaluated (figs. 2 and 3). The angle of the epiglottis was calculated by drawing a line parallel to the anterior aspect of the cervical bodies and a line through the axis of epiglottis at the posterior aspect of the tongue. The normal deflection of the epiglottis in adults and children is less than 45°.[5] In our patients, this relationship was observed in only nine (18%) of the children (fig. 1). However, nei-



EPIGLOTTIS >90°

FIG. 3. The upper portion of the cuff indents the base of the tongue at the level of C2. The lower portion cuff is opposite C6. The epiglottis is at an angle of greater than 90° to a line parallel to the anterior aspects of the cervical vertebral bodies.



LMA IN OROPHARYNX

FIG. 4. The LMA is in the oropharynx with the upper portion of the cuff indenting the mid-portion of the tongue and the lower portion adjacent to the epiglottis. The LMA is virtually perpendicular to the anterior cervical spine at the level of C2.

TABLE 4. The Pressure to Detect an Air Leak, the End-tidal CO_2, and the Respiratory Rates Relative to the Position of the Epiglottis

Position of LMA	Leak Pressure (H_2O)	End-tidal CO_2 (mmHg)		Respiratory Rate (breaths/min)	
		Mean	Maximum	Mean	Maximum
Oropharynx (n = 4)	18 ± 0.3 (17–19)	36 ± 5 (21–45)	39 ± 5 (26–47)	33 ± 0.4 (31–33)	38 ± 26 (34–43)
Anatomic					
<90° (n = 9)	23 ± 4 (15–42)	43 ± 3 (28–55)	47 ± 2 (33–55)	33 ± 3 (23–44)	38 ± 2 (24–50)
90° (n = 33)	21 ± 1 (16–28)	43 ± 1 (25–53)	46 ± 1 (25–57)	36 ± 2 (16–55)	39 ± 2 (19–55)
>90° (n = 4)	20 ± 2 (14–25)	38 ± 5 (33–50)	42 ± 4 (37–54)	31 ± 1 (29–35)	36 ± 1 (34–38)

Data are mean ± SE, with range in parentheses.

ther the position of the epiglottis nor the presence of the LMA in the oropharynx had any effect on ventilatory parameters (table 4).

Discussion

By reviewing the lateral scans we evaluated the mode by which the airway is maintained by the LMA. The cuff of the LMA by pushing the posterior part of the tongue forward overcame the backward deflection of the tongue that occurs during anesthesia in a supine subject.[6] Because the cuff is positioned between the base of the tongue above the epiglottis and below the laryngeal opening, it completely covered the laryngeal aperture, forming a low-pressure seal at the entrance of the larynx.

Age-related differences in the anatomy of the pharyngeal structures seem to have no effect on the integrity of the seal produced by the LMA. The glottis is higher and more anteriorly located in infants and children than in adults, the vocal cords are angled more forward than downward, and the epiglottis is larger and floppier. The pediatric LMAs are scaled-down versions of the adult form. The anatomic fit was as adequate in the infants as in the older children, where physical features already have the adult configuration. Possibly the softness of the cuff allows for easy adaptation to the differing pharyngeal characteristics found in various age groups. In comparing the position of the LMA relative to the cervical vertebrae, we observed that there were no differences in its position in the various age groups that required different sizes of LMA (table 3).

The other conspicuous radiologic observation was the posterior or downward deflection of the epiglottis after the insertion of the LMA (figs. 2 and 3). The interesting point here was that the position of the epiglottis had no bearing on the respiratory parameters. Further, neither the size of the LMA nor the age of the children had any bearing on the position of the epiglottis. In adults, downward deflection of the epiglottis has been noted by soft tissue radiography,[7] a finding occasionally made in children by fiberoptic laryngoscopy.[4,8] At times, repositioning of the device or reinsertion was thought necessary; an introducer was even designed with this in mind.[9] The reason for the characteristic deflection of the epiglottis is unknown. The relatively large cuff, above the base of the epiglottis, pushes the posterior aspect of the tongue forward, thus creating a space surrounding the epiglottis. With the patient supine, gravity also will enhance the posterior deflection of the epiglottis in the cavity of the cuff. We did not detect a compression of the epiglottis between the posterior aspect of the tongue and the cuff of the LMA. It seems that in children the area between the edges of the epiglottis and the rim of the mask aperture is sufficiently large to allow unobstructed ventilation. Posterior deflection of the epiglottis more than 45° is infrequently encountered and considered to be an abnormal finding; however, with an LMA in place, it is a frequent occurrence and seems to be of no consequence.

Earlier work with the LMA in adults has led investigators to state that the upper rim of the mask must lie against the epiglottis to guarantee a clear airway.[9] Our radiologic work with infants, children, and young adults does not confirm this. In our series the epiglottis was within the confines of the cuff in most of the instances and did not affect the ability of the LMA to maintain a patent airway.

Several other studies have evaluated the LMA in young patients.[2,4,9] In these studies the LMA was inserted on the first attempt in 90% of the cases, and on the second attempt in 8% of the cases. The most common problem with LMA insertion has been difficulty in maneuvering through the posterior curvature of the pharynx. Helpful clinical maneuvers to overcome this problem include: extension of the head, firm pressure on the hard palate to negotiate the posterior pharyngeal wall, slight lateral insertion of the device, insertion with the lumen facing backward following an 180° rotation, insertion of a finger on the posterior wall of the mask to act as a guide, and pulling the tongue forward with a dry swab.[4,10,11] Despite such attempts, a small number of children (2–5%) have remained difficult to manage.[4] Our own experience with children would have been similar; however, in these few instances when these maneuvers failed, we attributed our inability to posterior displacement of the base of the tongue; we managed these cases by lifting the tongue anteriorly with a laryngoscope before reattempting insertion. Use of a laryngoscope seemed more efficient and logical than repeated manipulations with the device itself, such attempts might risk damage to pharyngeal structures, most notably the pharyngeal tonsils. In general, laryngoscopy was needed only to lift the tongue forward.

In summary, we demonstrated that the LMA could be a helpful adjunct in maintaining an adequate airway during radiologic diagnostic procedures in children. We could delineate its position relative to the soft tissues of the pharynx and the cervical spine. We noted that its distal section was usually at the lower end of the hypopharynx, the cuff formed a seal around the opening of the larynx, and the epiglottis was deflected and located within the cuff of the LMA. On rare occasions the LMA was located high in the pharynx, but this did not seem to significantly affect the ventilatory parameters in the spontaneously breathing patient.

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