Laryngeal mask airway size selection in males and females: ease of insertion, oropharyngeal leak pressure, pharyngeal mucosal pressures and anatomical position†

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We have compared ease of insertion, oropharyngeal leak pressure, directly measured pharyngeal mucosal pressures and anatomical position (assessed fibreoptically) for the size 4 and size 5 laryngeal mask airway (LMA) in 20 male and 20 female patients. Microchip pressure sensors were attached to the LMA at locations corresponding to the piriform fossa, hypopharynx, base of the tongue, lateral and posterior pharynx, and the oropharynx. Oropharyngeal leak pressure, mucosal pressure and fibreoptic position were recorded during inflation of the cuff from 0 to 30 ml in 10-ml increments. In males, oropharyngeal leak pressure over the inflation range was higher for size 5 (21 *vs* 17 cm H_2O; $P=0.01$); mucosal pressure over the inflation range was higher in the posterior pharynx for size 4 (7 *vs* 2 cm H_2O; $P=0.007$), and higher in the piriform fossa (8 *vs* 5 cm H_2O; $P=0.003$) and hypopharynx (9 *vs* 5 cm H_2O; $P=0.003$) for size 5. In females, oropharyngeal leak pressure over the inflation range was the same (21 *vs* 21 cm H_2O), but mucosal pressure over the inflation range was higher in the piriform fossa (21 *vs* 8 cm H_2O; $P=0.03$) and posterior pharynx (4 *vs* 2 cm H_2O; $P=0.004$) for size 4, and higher in the lateral pharynx (5 *vs* 1 cm H_2O; $P=0.01$) and oropharynx (11 *vs* 5 cm H_2O; $P=0.009$) for size 5. The distribution of mucosal pressure was different for size 4 between males and females, but not for size 5. For both males and females, fibreoptic position was similar. We conclude that the size 5 LMA is optimal in males, but either size is suitable for females. The shape of the pharynx may be different between males and females.

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Optimal size selection is critical to the safe and effective use of the laryngeal mask airway (LMA).[1] Ideally, the optimal LMA should be easy to insert; have an oropharyngeal leak pressure sufficient for positive pressure ventilation; a pharyngeal mucosal pressure less than capillary perfusion pressure; and be positioned such that instruments pass easily into the respiratory tract. Vogagis, Batziouulis and Secha-Doussaitou[2] and Brimacombe and colleagues[3] showed that a sex-related formula (size 4 for females; size 5 for males) was a more successful strategy[2 3] than the manufacturer's weight-based recommendations (size 3, 30–70 kg; size 4, >70–90 kg; size 5, >90 kg). Berry and colleagues found that the size 5 LMA was optimal in 63% of adult patients, the size 4 in 37% and the size 3 was never optimal.[4] Asai and colleagues found that sizes 4 and 5 were superior to sizes 3 and 4 for females and males, respectively, and did not produce higher pressures on the pharyngeal mucosa.[5] A limitation of this latter study was that the authors did not measure mucosal pressure directly, but instead was calculated by subtracting *in vivo* from *in vitro* intracuff pressures, a technique that has been shown to be inaccurate.[6]

In this study, we have investigated if there are any differences between the size 4 and size 5 LMA for males and females in terms of ease of insertion, oropharyngeal leak pressure, directly measured pharyngeal mucosal pressures and anatomical position (assessed fibreoptically).

†This article is accompanied by Editorial II

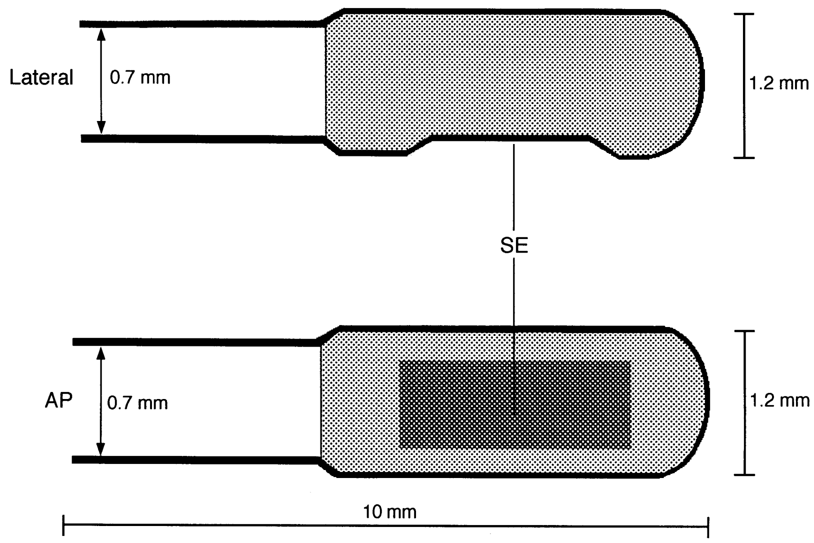

Fig 1 Lateral and anteroposterior (AP) view of the sensor (shaded) and cable. The sensing element (SE) is directed towards the mucosa.

Patients and methods

We studied 20 male and 20 female ASA I–II adult patients, allocated randomly to receive either the size 4 or size 5 LMA for airway management, after obtaining Ethics Committee approval and informed consent. Patients were excluded if they were less than 18 yr, had respiratory tract pathology, were at risk of aspiration or were considered otherwise unsuitable for LMA use. Pharyngeal mucosal pressures were measured using six strain gauge silicone microchip sensors (Codman MicroSensor, Johnson and Johnson Medical Ltd, Bracknell, UK) attached to the external surface of the LMA with clear adhesive dressing, 45 µm thick (Tegaderm, 3M, Ontario, Canada). The sensors had a diameter of 1.2 mm, functional pressure range –50 to 250 mm Hg, temperature sensitivity less than 0.1 mm Hg $°C^{-1}$, zero drift $<$3 mm Hg/24 h, frequency response 0–10 Hz and were accurate to $\pm$2%. The flat rectangular sensing element was located in the lateral wall of the sensor, 1 mm proximal to the tip and orientated at 90° to the longitudinal axis of the sensor (Fig. 1). The cable had a diameter of 0.7 mm. Attachment of the sensors was performed manually by placing the sensor in the correct position on the LMA and then overlaying it with adhesive dressing. The sensing element was orientated such that its flat surface was parallel to and directed 90° away from the LMA surface. This ensured that the flat surface of the sensing element was facing the mucosa. The position–orientation of all sensors were checked *in vitro* over the entire inflation range before and after use in each patient by visual inspection. The sensors were zeroed after attachment to the LMA. The accuracy of the measurement system was tested *in vitro* before and after use in each patient by submerging the cuff portion in water at 37°C to a depth of 13.6 cm (10 mm Hg) and 40.8 cm (30 mm Hg) and noting the pressure readings from each sensor. The sensors were attached to the following locations on the LMA (corresponding mucosal area): (A) anterior middle part of the cuff side (piriform fossa); (B) posterior tip of the cuff (hypopharynx); (C) anterior base of the cuff (base of the tongue); (D) posterior middle part of the cuff side (lateral pharynx); (E) backplate (posterior pharynx); and (F) posterior tube (oropharynx) (Fig. 2). Non-midline sensors were placed on the left side.

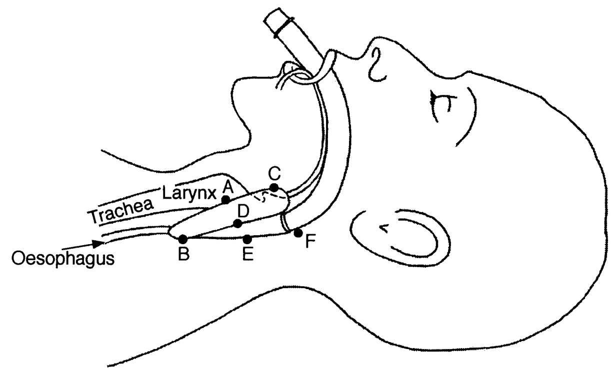

Fig 2 Location of sensors on the laryngeal mask airway (corresponding mucosal area): A=anterior middle part of the cuff side (piriform fossa); B= posterior tip of the cuff (hypopharynx); C=anterior base of the cuff (base of the tongue); D=posterior middle part of the cuff side (lateral pharynx); E= backplate (posterior pharynx); and F=posterior tube.

Anaesthesia was standardized and routine monitoring was applied. Anaesthesia was induced with propofol 2.5 mg kg^{-1} and maintained with 1–2% sevoflurane and 100% oxygen. Nitrous oxide was avoided to prevent any increase in cuff volume from diffusion.[7] Neuromuscular block was produced with atracurium 0.5 mg kg^{-1}. A single experienced LMA user ($>$1500 uses) inserted–fixed the LMA according to the manufacturer's instructions.[8] The number of attempts taken to insert the device was recorded. A maximum of three attempts was allowed. A failed attempt was defined as removal of the device from the mouth. The pilot balloon was attached via a three-way tap to a 10-ml

Table 1 Physical characteristics, number of insertion attempts, oropharyngeal leak pressure (OLP), fibreoptic score (FOS), intracuff and mucosal pressures obtained over the inflation range (0–30 ml) for the size 4 compared with the size 5 laryngeal mask airway in males and females. Data are mean (95% CI) or number. Fibreoptic score: 4=only vocal cords visible, 3=vocal cords and posterior epiglottis, 2=vocal cords and anterior epiglottis, 1=vocal cords not seen.[9] *Non-normally distributed

	Males			Females		
	Size 4 (n=10)	Size 5 (n=10)	P	Size 4 (n=10)	Size 5 (n=10)	P
Age (yr)	32 (26–39)	33 (24–42)		36 (30–42)	33 (26–39)	
Weight (kg)	75 (71–80)	76 (70–82)		66 (58–73)	64 (55–73)	
Height (cm)	176 (172–180)	177 (172–180)		165 (162–168)	165 (160–169)	
Body mass index (kg m^{-2})	24 (23–25)	24 (23–26)		23 (21–25)	23 (21–26)	
Insertion attempts (1/2/3)	10/0/0	10/0/0	ns	10/0/0	10/0/0	ns
OLP (cm H_2O)	17 (14–20)	21 (19–24)	0.01	21 (19–24)	21 (18–24)	ns
FOS (4/3/2/1)	8/21/9/2	9/20/11/0	ns	11/21/4/4	3/23/10/4	ns
Intracuff pressure (cm H_2O)	66 (39–93)	43 (26–61)	0.004	71 (45–96)	53 (32–74)	0.003
Mucosal pressure (cm H_2O)						
Piriform fossa	5 (4–6)	8 (7–10)	0.003	21 (11–31)	8 (6–10)	0.03
Hypopharynx	5 (3–7)	9 (6–12)	0.003	10 (5–15)	8 (6–11)	ns
Base of tongue	7 (4–10)	10 (6–14)	ns	10 (7–14)	12 (8–17)	ns
Lateral pharynx	3 (2–4)	2 (1–3)	ns	1 (1–2)*	5 (3–6)	0.01
Posterior pharynx	7 (2–12)	2 (1–2)	0.007	4 (3–5)	2 (1–2)	0.004
Oropharynx	14 (9–20)	12 (9–16)	ns	5 (3–8)	11 (7–15)	0.009

syringe and a calibrated pressure transducer. Intracuff pressure was reduced to –55 cm H_2O *in vitro*. Pharyngeal mucosal pressures, intracuff pressures, oropharyngeal leak pressures and fibreoptic position were documented at zero volume and after each additional 10 ml up to 30 ml. Air was used to fill the cuff. The fibreoptic position of the LMA was determined using the following scoring system: 4=only vocal cords visible; 3=vocal cords and posterior epiglottis visible; 2=vocal cords and anterior epiglottis visible; 1=vocal cords not seen.[9] Any displacement of the cuff from the periglottic tissues or rotation in the sagittal plane was noted. Measurements were made with the patient in the supine position and the head–neck in the neutral position with the occiput on a firm pillow, 7 cm in height. Oropharyngeal leak pressure was measured by closing the expiratory valve of the circle system at a fixed gas flow of 3 litre min^{-1}, and noting the airway pressure at which the dial on the anaeroid manometer reached equilibrium.[10] The position of the anterior tip sensor was verified at the end of the procedure by observation of a pressure spike during application of gentle cricoid pressure.

Sample size was based on oropharyngeal leak pressure data obtained from a crossover study of 13 male and 17 female patients managed with the size 4 and size 5 LMA for a type I error of 0.05 and a power of 0.9.[4] Statistical comparisons of oropharyngeal leak pressure, fibreoptic score, intracuff and mucosal pressures were made from data obtained over the inflation range (0–30 ml). The distribution of data was determined using Komolgorov–Smirnov analysis.[11] Statistical analysis of airway sealing and mucosal pressures was with a paired t test (normally distributed data) and Friedman's two-way analysis of variance (non-normally distributed data). The chi-square test was used to compare fibreoptic scores. Unless otherwise stated, data are presented as mean (95% confidence intervals). Significance was taken as $P<0.05$. Statistical analysis was performed on an IBM computer using SYSTAT v 7.0.

Results

Patient characteristics and LMA data over the inflation range are presented in Table 1. Oropharyngeal leak pressures, fibreoptic scores, intracuff and mucosal pressures with increasing cuff volume are presented in Table 2 (males) and Table 3 (females). All LMA were inserted at the first attempt and were positioned correctly, as judged by fibreoptic laryngoscopy and the cricoid pressure spike. The position–orientation of the sensors were identical and pressures were accurate before and after use. There was no displacement of the cuff from the periglottic tissues and no rotation in the sagittal plane. There were no differences in physical characteristics of the males and females in the size 4 and size 5 groups.

For both males and females, intracuff pressure was higher with the size 4 and fibreoptic scores were similar. In males, oropharyngeal leak pressure over the inflation range was higher for size 5; mucosal pressure over the inflation range was higher in the posterior pharynx for size 4, and higher in the piriform fossa and hypopharynx for size 5 (Table 1). In females, oropharyngeal leak pressure over the inflation range was the same for sizes 4 and 5, but mucosal pressure over the inflation range was higher in the piriform fossa and posterior pharynx for size 4, and higher in the lateral pharynx and oropharynx for size 5 (Table 1). In all groups, oropharyngeal leak pressure increased significantly from 0 to 10 ml and from 10 to 20 ml, but remained unchanged or decreased with cuff volumes from 20 to 30 ml (Tables 2, 3).

Mucosal pressure increased with increasing cuff volume, but the rate of increase varied between locations and the pressures were not evenly distributed. In males, the highest

Table 2 Oropharyngeal leak pressures (OLP), fibreoptic score (FOS), intracuff and mucosal pressure at each cuff volume for male patients. Size 4 *vs* 5 laryngeal mask airway (LMA). Data are mean (95% CI) or number. Pressures are in cm H_2O. Fibreoptic score: 4=only vocal cords visible, 3=vocal cords and posterior epiglottis, 2=vocal cords and anterior epiglottis, 1=vocal cords not seen[9]

Vol. (ml)	OLP	FOS (*n*) (4/3/2/1)	Intracuff	Piriform fossa	Hypopharynx	Base of tongue	Lateral pharynx	Posterior pharynx	Oropharynx
Size 4									
0	9 (5–12)	2/5/2/1	–28 (–31 to –24)	3 (1–5)	1 (0–2)	1 (0–2)	1 (0–3)	2 (0–3)	2 (0–4)
10	16 (11–21)	2/6/1/1	29 (15–42)	4 (1–7)	3 (0–6)	5 (2–8)	2 (0–3)	6 (0–12)	11 (4–17)
20	23 (16–30)	3/5/2/0	70 (56–83)	5 (3–8)	7 (2–11)	9 (3–15)	4 (0–7)	11 (2–28)	21 (6–34)
30	20 (15–26)	1/5/4/0	194 (177–211)	6 (3–10)	9 (3–15)	13 (4–22)	4 (0–8)	11 (2–25)	24 (10–39)
Size 5									
0	13 (9–17)	0/7/3/0	–23 (–29 to –23)	6 (3–10)	4 (1–6)	1 (-1–3)	0 (0–1)	1 (0–1)	5 (1–10)
10	20 (15–25)	1/6/3/0	30 (12–48)	8 (5–12)	5 (3–7)	8 (1–14)	2 (1–3)	2 (1–2)	7 (1–14)
20	25 (20–31)	3/5/2/0	56 (36–75)	10 (5–14)	11 (6–16)	15 (5–25)	3 (0–6)	2 (1–2)	14 (6–21)
30	26 (21–31)	5/2/3/0	110 (87–134)	9 (5–12)	17 (9–25)	17 (8–26)	3 (0–6)	2 (1–3)	23 (15–32)

Table 3 Oropharyngeal leak pressures (OLP), fibreoptic score (FOS), intracuff and mucosal pressures for each cuff volume for female patients. Size 4 *vs* 5 laryngeal mask airway (LMA). Data are mean (95% CI) or number. Pressures are in cm H_2O. Fibreoptic score: 4=only vocal cords visible, 3=vocal cords and posterior epiglottis, 2=vocal cords and anterior epiglottis, 1=vocal cords not seen[9]

Vol. (ml)	OLP	FOS (*n*) (4/3/2/1)	Intracuff	Piriform fossa	Hypopharynx	Base of tongue	Lateral pharynx	Posterior pharynx	Oropharynx
Size 4									
0	12 (8–15)	3/6/0/1	–24 (–29 to –20)	16 (2–36)	2 (0–3)	5 (1–11)	1 (0–1)	2 (0–4)	2 (0–4)
10	21 (17–26)	3/6/0/1	36 (26–46)	20 (3–41)	7 (2–12)	7 (1–15)	1 (0–2)	4 (2–6)	5 (0–8)
20	27 (25–30)	3/6/0/1	80 (64–95)	17 (3–30)	11 (6–17)	12 (4–20)	2 (1–3)	4 (2–6)	7 (2–13)
30	25 (22–28)	2/3/4/1	190 (171–210)	29 (2–61)	21 (2–40)	16 (8–24)	2 (1–3)	5 (3–7)	8 (2–15)
Size 5									
0	13 (10–17)	0/6/3/1	–28 (–34 to –22)	6 (2–9)	2 (0–4)	3 (–1–6)	3 (0–6)	1 (0–3)	3 (0–6)
10	19 (14–24)	1/6/2/1	29 (13–46)	7 (3–11)	5 (1–9)	7 (1–13)	5 (1–8)	2 (1–3)	6 (1–12)
20	26 (21–31)	1/7/1/1	82 (62–103)	9 (5–13)	10 (6–15)	18 (7–28)	5 (2–8)	2 (1–3)	14 (7–22)
30	27 (20–33)	1/4/4/1	129 (97–129)	10 (5–14)	17 (10–23)	21 (8–34)	5 (2–9)	2 (1–3)	22 (12–32)

mucosal pressure with the size 4 and size 5 was in the oropharynx at a cuff volume of 30 ml (Table 2). In females, the highest mucosal pressure was in the piriform fossa with the size 4 at a cuff volume of 30 ml, and in the oropharynx and at the base of the tongue with the size 5 at a cuff volume of 30 ml (Table 3). The distribution of mucosal pressure was different for the size 4 between males and females, but not for the size 5.

Discussion

A fundamental difficulty in predicting optimal LMA size is that the relationship between sex, weight, height and pharyngeal geometry is inconsistent.[12] The complexity of these relationships has been highlighted by a recent study which suggested a correlation between increasing body mass index and decreasing pharyngeal height.[13] Berry and colleagues showed that there was no correlation between sex, weight, height and body mass index or any other easily measured anatomical variable and optimal LMA size.[4] In a study of 300 patients, Vogagis, Batziouulis and Secha-Doussaitou[2] compared the manufacturer's weight-based recommendations (size 3, 30–70 kg; size 4, $>$70–90 kg; and size 5 $>$ 90 kg) with a sex-related formula (size 4 for females; size 5 for males) and showed that the sex-related formula was a more successful strategy[2 3] in terms of oropharyngeal leak pressure. In a crossover study of 30 patients, Berry and colleagues showed that sizes 4 and 5 LMA were more suitable for adults than the size 3 at intracuff pressures of 60 cm H_2O[4] in terms of oropharyngeal leak pressure and fibreoptic position. The size 5 usually had a higher oropharyngeal leak pressure than the size 4, but both provided an adequate seal and fibreoptic view of the vocal cords. In a crossover study, Asai and colleagues compared sizes 3 and 4 in 30 females and sizes 4 and 5 in 30 males and showed that the larger mask provided a better seal than the smaller size without producing higher pressures on the pharynx.[5]

We have shown that the size 5 was better than the size 4 in males, but either size was suitable for females. In males, both sizes were easy to insert, had a similar fibreoptic position and mucosal pressures, but oropharyngeal leak pressure was higher for the size 5. In females, both sizes were easy to insert, had similar oropharyngeal leak pressures, mucosal pressures and fibreoptic position. Mean mucosal pressures for both sexes and sizes were well below those considered safe for prolonged tracheal intubation[14] and were similar to those found in an earlier study by this group.[6] We have confirmed the finding of Berry and colleagues[4] that the single most appropriate size for adults is the size 5. This may have implications for provision of LMA outside the operating room, such as on the wards, in recovery rooms, accident and emergency, ambulances and helicopters, where placement of a variety of adult sizes may be prohibitive because of lack of space and/or cost.

The distribution of mucosal pressure was similar with the size 5 for males and females, but different with the size 4. We speculate that this may be related to differences in pharyngeal shape and compliance between males and females. These differences would be more apparent with the smaller size as, for a given cuff volume, the surface would be more rigid and therefore less able to adapt to different anatomical shapes and compliances. A literature search failed to reveal published data on sex differences in pharyngeal shape and compliance.

We conclude that the size 5 LMA was optimal in males, but either size was suitable for females. The shape of the pharynx may be different between males and females.

References

1 Brimacombe J, Brain AIJ, Berry A. *The Laryngeal Mask Airway: Review and Practical Guide*. London: WB Saunders Company Ltd, 1997

2 Voyagis GS, Batziouulis PG, Secha-Doussaitou PN. Selection of the proper size of laryngeal mask airway in adults. *Anesth Analg* 1996; **83**: 663–4

3 Brimacombe J, Berry A, Campbell RC, Verghese C. Selection of the proper size of laryngeal mask airway in adults. *Anesth Analg* 1996; **83**: 664

4 Berry A, Brimacombe J, McManus KF, Goldblatt M. An evaluation of the factors influencing selection of the optimal size of laryngeal mask airway in normal adults. *Anaesthesia* 1998; **53**: 565–70

5 Asai T, Howell TK, Koga K, Morris S. Appropriate size and inflation of the laryngeal mask airway. *Br J Anaesth* 1998; **80**: 470–4

6 Keller C, Brimacombe J, Benzer A. Calculated *vs* measured pharyngeal mucosal pressures with the laryngeal mask airway during cuff inflation: assessment of four locations. *Br J Anaesth* 1999; **82**: 397–9

7 Lumb AB, Wrigley MW. The effect of nitrous oxide on laryngeal mask cuff pressure. In vitro and in vivo studies. *Anaesthesia* 1992; **47**: 320–3

8 Brimacombe J, Brain AIJ, Berry A. *The Laryngeal Mask Airway Instruction Manual*. Henley-on-Thames: Intavent Research Ltd, 1996

9 Brimacombe J, Berry A. A proposed fiber-optic scoring system to standardize the assessment of laryngeal mask airway position. *Anesth Analg* 1993; **76**: 457

10 Keller C, Brimacombe JR, Keller K, Morris R. Comparison of four methods for assessing airway sealing pressure with the laryngeal mask airway in adult patients. *Br J Anaesth* 1999; **82**: 286–7

11 Sachs L. Der Kolmogoroff–Smirnov-Test fuer die Guete der Anpassung. In: *Angewandte Statistik*. Berlin: Springer Verlag, 1992; 426–30

12 Tham LCH. Children and size of laryngeal masks. *Can J Anaesth* 1994; **41**: 354

13 Goodman EJ, Eisenmann UB, Dumas SD. Correlation of pharyngeal size to body mass index in the adult. *Anesth Analg* 1997; **84**: S584

14 Lewis FR, Schlobohm RM, Thomas AN. Prevention of complications from prolonged tracheal intubation. *Am J Surg* 1978; **135**: 452–7