EQUIPMENT

A. Endotracheal tube (ETT)

UNcuffed ETT

AGE	WT(KG)	*ID(MM)	**ORAL LENGTH (MM)	**NASAL LENGTH (MM)
neonate	< 1 (less than 28 weeks gestational age)	2.5	5.5	7
neonate	1- 2 (28-34 weeks gestational age)	3.0	7- 8	8.5- 10
neonate	> 2-4 (34 weeks to term neonate)	3.5	9-10	11-12
3 months	6	3.5-4	10	12
6 months	8	4.0	10-11	12-13
12 months	10	4.5	11-12	13-14

Although there are many guidelines available, it is the usual practice to prepare, in addition, ETTs that are half a size larger and smaller than the estimated size. The tube should not fit tightly, a small leak is advisable. Always test for leak by holding a sustained pressure of about 15 cm H2O. After intubation, always listen in both axillae and epigastric areas.

In general, the following formulae can be used for uncuffed ETTs in children:

ETT size (ID) : age(yrs)/4 + 4 or 4.5 for patients >2 years

For our local population, the formula ETT size (uncuff ID): age (yrs)/4 +4.5 appears to be more appropriate

* ID internal diameter ** estimated depth of ETT insertion

Cuffed Paediatric ETT

Traditionally, cuffed ETTs were recommended for children >8yrs. However, the Microcuff* ETT is designed specifically for the pediatric airway, and has a short cylindrical high volume low pressure cuff near the ETT tip. It affords a lower risk of airway trauma and mucosal tissue injury. The use of Microcuff tube should be used only for infants who would otherwise be intubated with uncuffed ETT size 3.5mm ID and larger. The use of a low pressure cuffed ETT affords fewer ETT exchanges due to incorrect sizing of ETT and less leakage during ventilation without causing an increase in acute postextubation complications and complications associated with multiple laryngoscopy and intubation attempts. The cuff pressure must be measured and ideally kept at 20 cm H2O or below. Cuff tubes should not be used in neonates. We currently have Microcuff ETTs from size 3.0mm ID to 6.0mmID in our institution..

Other cuff ETT brands can be considered if 5.0mm ID or larger cuffed ETT is required.

In general, the following formula can be used for cuffed ETT in children:

ETT size (ID): age/4 + 3.5 (except neonates)

Microcuff ETT

Recommended Sizing for Children (Halyard health):

Microcuff ETT ID (mm)	Age
3.0	Term ≥ 3 kg- < 8 months
3.5	8 months- < 2 years
4.0	2 years- < 4 years
4.5	4 years- < 6 years
5.0	6 years- < 8 years
5.5	8 years- < 10 years
6.0	10 years - < 12 years
6.5	12 years- < 14 years
7.0	14 years- < 16 years

ETT Insertion Depth

Although various formulae exist to predict the correct ETT insertion depth, these formulae generally have a poor accuracy rate particularly weight based formulae because the growth of children is non linear.. Nevertheless they can be used as a guide for initial placement. Alternatively, the depth marker on the ETT (located at the distal end of the ETT) can be used to guide placement at the vocal cord level but these depth markers can vary between ETT manufacturers and studies have shown these do not guarantee optimal placement.

Therefore, It is important after intubation to auscultate the lungs to confirm the absence of endobronchial intubation and have the position of the ETT confirmed with Chest X Ray if the patient needs to remain intubated postoperatively. Ideally the ETT tip should sit mid tracheal. It is important to realise that neck movements in the neonate or young infant can result in substantial movement of the ETT, making it possible for inadvertent extubation with neck extension and endobronchial intubation with neck flexion. The ideal position is for the tip of the ETT to be at the junction between the middle and distal third of the trachea.

For children over 1 year of age:

Insertion depth (cm) for orotracheal intubation= age/2+13 or height (cm)×0.1+3

Insertion depth (cm) for nasotracheal intubation= age/2+15

For children under 1 year of age:

Insertion depth (cm) for orotracheal intubation= weight/2+8 or weight (kg)+6

Insertion depth (cm) for nasotracheal intubation=weight/2+9

Photo showing the depth marker on the portex ETT

A recent study of 167 intubated children ranging from infants beyond the first 28 days of life to 17.9 years had their chest X-rays analysed for optimal positioning of the tip of the ETT situated between middle and third of the trachea based on age, weight and height to develop regression models and tables/graphs to allow for fast and accurate determination of ETT insertion depths in children. Generally age and height based formulae predict optimal ETT depth more accurately for children less than weight based formulae. The results are summarised in the 2 tables below.

Table 1

Age-based, weight-based and height-based categories with the corresponding optimal ETT tip-to-carina distance

Category	Age (years)	Weight (kg)	Height (cm)	Average tracheal length (cm)	Optimal ETT tip-to-carina distance (cm)
1	0–0.25	>3–6	>48–60	4.2	1.4
2	>0.25–2.0	>6–12	>60–88	5.1	1.7
3	>2–4	>12–16	>88–105	6.4	2.1
4	>4–10	>16–35	>105–140	8.0	2.7
5	>10–14	>35–50	>140–165	10.0	3.3
6	>14–18	>50	>165	12.0	4.0

- The optimal ETT tip-to-carina distance is defined based on the average tracheal lengths determined by Griscom and Wohl and Luscan *et al*. Conrardy *et al* recommend a target ETT tip position between the middle third and distal third of the trachea.[14–16]

Table 3 Data table with height-related ETT insertion depth recommendations interpolated from the corresponding best-fit curves

Height range (cm)	ETT depth (cm)
43–48	9.5
49–54	10.0
55–60	10.5
61–66	11.0
67–72	11.5
73–78	12.0
79–83	12.5
84–89	13.0
90–94	13.5
95–99	14.0
100–104	14.5
105–109	15.0
110–114	15.5
115–119	16.0
120–123	16.5
124–128	17.0
192–133	17.5
134–137	18.0
138–142	18.5
143–146	19.0
147–151	19.5
152–155	20.0
156–160	20.5
161–164	21.0
165–168	21.5
169–173	22.0
174–177	22.5
178–181	23.0
182–185	23.5

ETT, endotracheal tube.

Ebenebe CU, Schriever K, Apostolidou S, et al.Recommendations for endotracheal tube insertion depths in children.Emergency Medicine Journal 2023;40:583-587

B. Laryngeal Mask Airway (LMA)

Recommended sizes are:

Size	Weight (kg)	Max cuff inflation vol (ml)
1	5	up to 4
1.5	5 - 10	up to 7
2	10 - 20	up to 10
2.5	20 - 30	up to 14
3	30 - 50	up to 20
4	50 - 70	up to 30
5	70 - 100	up to 40

Cuff pressures must be checked and confirmed not to exceed60 cm H_2O, although ideally keeping the cuff pressure 40-50cm H2O is recommended.

In our institution we tend to use size 2.5 for children 17 kg and above.

ProSeal LMA

ProSeal LMA is available for use in well fasted patients with no risk of regurgitation or aspiration. Choose size as for regular LMAs.

Intubation via LMA

Patients can be intubated via LMAs.

The largest ETT & fibreoptic bronchoscope (FOB) that can be used with each LMA is given in the table below.

Recommended LMA , FOB and ETT Size (mm) for intubation:

LMA Size	Maximum FOB Size	Maximum ETT size
1	2.8mm	3.5mm Uncuffed
1.5	3.0mm	4.0mm Uncuffed
2	3.5mm	4.5mm Uncuffed
2.5	4.0mm	5.0mm Uncuffed
3	5.0mm	6.0mm Cuffed
4	5.0mm	6.0mm Cuffed
5	5.5mm	7.0mm Cuffed

*FOB: FiberOptic Bronchoscope

Our dept has FOB in the following sizes:

1. 2.2mm
2. 2.8mm
3. 3.6mm

The table below indicates the smallest ETT & LMA that can be used with each FOB.

FOB	Diameter (mm)	Smallest ETT	Smallest LMA
paed	2.8	3.5*	1.0
neonatal	2.2	2.5*	1.0

* snug fit- must remove ETT blue connector before railroading over FOB. FOB must be well lubricated with silicone spray.

C. One Lung Ventilation (OLV) in Children

As in adults, OLV in children may be indicated to facilitate surgical exposure or alveolar lavage, anatomically isolate the lungs to avoid cross contamination in cases of empyema or pulmonary hemorrhage or to facilitate more effective ventilation in cases of bronchial disruption or bronchopulmonary fistula.

The options available are:

1. endobronchial intubation
2. bronchial blocker
3. double lumen tube

Age	mainstem bronchus		endobronchial intubation with uncuffed ETT (OD mm)		Endobronchial intubation with cuffed ETT (ODmm)	
	R	L	R	L	R	L

0-3 months	4.4	3.6	3 (4.2)	2.5 (3.6)	3 (4.3)	-
3-6 months	4.7	3.9	3 (4.2)	2.5 (3.6)	3 (4.3)	-
6-12 months	5.4	4.2	3.5 (4.9)	3 (4.2)	3.5 (4.9)	3 (4.3)
1-2 years	5.4	5.6	4 (5.2)	3.5 (4.9)	4 (5.6)	3.5 (4.9)
2-4 years	7.5	6.6	4.5 (6.2)	3.5 (4.9)	4.5 (6.2)	3.5 (4.9)
4-6 years	8.3	7.3	4.5 (6.2)	4 (5.5)	4.5 (6.2)	4 (5.6)
6-8 years	8.9	7.8	5.5 (7.5))	5 (6.9)	5.5 (7.5)	5 (6.9)
8-10 years	9.9	8.8			6 (8.2)	5 (6.9)
10-12 years	10	7.7			6.5	6
12-14 years	11.2	8.6			7	6.5
14-16	12	9.2			7	6.5
16-18	11.8 (F) 13.5 (M)	9 (F) 10.4 (M)			7-7.5	6.5-7

0-10 years: source (An Update on One-Lung Ventilation in Children. Anesthesia & Analgesia, 2020)
10-18 years: source (Paediatric lung isolation. BJA Education, 17 (2): 57–62 (2017)

Anatomical considerations:

1. The left bronchus is consistently smaller than the right bronchus so a smaller ETT has to be chosen for endobronchial intubation
2. It is technically more challenging to isolate the right lung because of the take off for the right upper lobe remains very close to the carina (≤1 cm) in patients up to 8 years
3. It is technically easier to achieve left lung isolation and safely adjust the position of bronchial blockers because the take off for the left upper lobe bronchus is 3 times the distance compared to the take off for the right upper lobe bronchus from the carina.

Recommended sizes of OLV devices in children of different age based on availability in our institution:

Options for Lung Isolation	**Sizes available for paediatric use**	**Preferred method for ages**
Single-lumen ETT (endobronchial)	2.5 mm ID and up	0-6 months
Vascular balloon catheter (Fogarty)	3,4,5 French (Fr)	6 months --8 years below 2 years (external or parallel placement) above 2 years (internal or external placement)
Arndt bronchial blocker	5 Fr (OD 2.5mm) 7 Fr (OD 2.3 mm)	6 months -8 years below 2 years (external or parallel placement) above 2 years (internal or external placement)
Uniblocker tube (Fuji Systems)	5 Fr (OD 1.7mm) 9 Fr (OD 3.0mm)	6 months -8 years below 2 years (external or parallel placement) above 2 years (internal or external placement)

Univent tube	3.5 mm ID (OD 7.5/8mm*)	6-8 years
	4.5 mm ID (OD 8.5/9.0mm*)	10-12 years
Double-lumen tube	26 Fr (OD 8.7mm) 28 Fr (OD 9.3mm) 35 Fr (OD 10.7mm) 37 Fr (OD 12.3mm)	8-18 years

* Sagittal/transverse

In order for a bronchial blocker and bronchoscope to physically fit together inside the lumen of the tracheal tube (coaxial technique), the OD of the bronchial blocker (ODBB) and the OD of the bronchoscope (ODB) added together needs to be <90% of the ID of the tracheal tube.

To allow for adequate ventilation during bronchoscopy, the tracheal tube should not be >50% blocked.

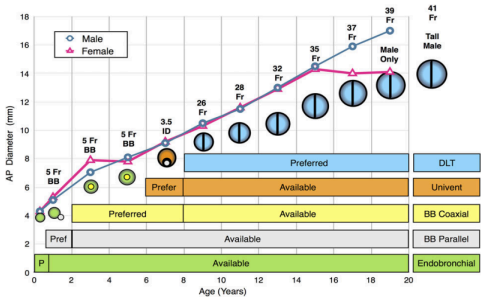

Fig 2 Anteroposterior trachea diameter vs age for male and female paediatric patients. Trachea diameters are from cadaveric[5] and radiologic[6] studies. Male and female airway sizes are similar until 15 yr of age, when the female trachea stops growing, but the male trachea continues to grow. Superimposed is the preferred airway device for lung isolation for a given age, placed on the graph at the given diameter of the device. Note that in order to use an airway device for a certain age, the diameter of that device must be smaller than the trachea AP diameter at that age. DLT, double-lumen tracheal tube; Univent, Fuji Univent tracheal tube; BB coaxial, bronchial blocker coaxial technique; BB parallel, bronchial blocker parallel technique; Endobronchial, endobrochial intubation with an SLT.

source: Paediatric lung isolation. BJA Education, 17 (2): 57–62 (2017)

The table below shows the recommended sizing of each of the techniques described above, according to the age of the infant or child. As with all equipment, however, correct sizing will vary between patients of the same age and so it is essential to have a range of sizes available

Age (yr)	Ardnt (Fr)	Fuji Uniblocker (Fr)	Univent (ID mm)	DLT (Fr)
0.-3 months	5 (E)	5 (E)		
3-6	5 (E)	5 (E)		

6-12	5 (E))	5 (E)		
1-2	5 (E)	5 (E)		
2-4	5 (E/I), 7(E)	5 (E/I)		
4-6	5 (E/I) 7(E)	5 (E/I)		
6-8	5 (E/I) 7(E/I)	5 (E/I)	3.5	
8-10	7 (E/I) 9(E/I)	9 (E/I)	3.5	26
10-12	9 (E/I)	9 (E/I)	4.5	26,28
12-14	9	9	6	32
14-16	9	9	6.5	35, 37
16-18	9	9	7.0	37,39, 41

E:bronchial blocker placed external or parallel to the endotracheal tube
I: bronchial blocker placed internal or coaxial to the endotracheal tube

Fogarty Catheter- balloon Inflation volume & diameter

Size(F)	3	4	5
Inflation vol (ml)	0.25	0.5	0.75
Diameter (mm)	8	9	10

D. Laryngoscopes

- Straight blade (Miller and Seward): for use in neonates and those younger than 3 months old.
- Small curved blade (Magill) can be used for those older than 3 months old.
- VideoLaryngoscopes:
  Glidescope- recommended stat sizes for children

STAT Size	Body Weight
stat 0	< 1.5 kg
stat 1	1.5- 3.6 kg
stat 2	1.8- 10 kg
stat 2.5	10- 28 kg

E. Breathing Systems

Ayre's T- piece with Jackson Rees modification (Mapleson F)

Advantages: low resistance (no valves), minimal dead space lightweight, long compression volume allowing the operator to have a good feel of lung compliance, and inexpensive.This makes it a suitable choice if rapid volatile anaesthetic induction is desired in small children less than 10kg, even though this circuit may be used for children up to 20kg.
Unless attached to a heated humidifier, gas delivered to the patient will be cold and dry, predisposing the patient to heat loss from the respiratory system.

A pressure gauge should be used to measure ventilating pressures when ventilating on a T piece circuit.

In order to prevent rebreathing of carbon dioxide in the circuit, a minimal gas flow rate of 2-3 times the minute ventilation of the patient who is spontaneously breathing should be set, with a minimal flow rate of 3L/min. As such, running a volatile anaesthetic using this circuit will be uneconomical in bigger children.

The bag may be replaced with a mechanical ventilator if controlled ventilation is desired. If so, the fresh gas flow rate to achieve normocapnia is 1000 ml + 100-200ml/kg/min. Controlled ventilation with this circuit is rarely practiced these days, with a preference to switch to a circle system which has greater advantages such as allowance for positive end expiration pressure (PEEP) and low flow anaesthesia.

Circle system

Advantages: ability to conserve moisture and heat, lower gas flows down to less than 1L/min may be used making it more economical when using expensive inhalational agents e.g. sevoflurane.

It can be used for spontaneous respiration or controlled positive ventilation.However because there are valves and the presence of a carbon dioxide absorber in the circuit, the resistance in the circuit may increase the work of breathing for spontaneously breathing children less than 10kg, in which case pressure support ventilation is advised. The dead space is also considerable, resulting in delays to changes to the concentration of volatile anaesthetics in the circuit.. Different circuit diameters are used for neonates, children less than 30kg and those 30 kg and above.

F. Invasive Monitoring Lines

Disposable transducer sets are used – please let the Anaesthesia nurses know if you require a double or triple transducer set.
The following are general recommendations based on an average sized child. If the patient is smaller or larger than expected, up or downsize as appropriate.

- RADIAL Arterial lines :
  Up to 3/12 or weight<5kg :24G terumo venula
  > 3/12 or weight >10kg -40kg :22G terumo venula
  > 10yr or weight>40kg22-:20G terumo venula

- FEMORAL Arterial lines:
  Leaderflex catheters are available in 22G 4cm for children < 10kg
  Leadercath catheters are available in 20G & 18G 8 cm for children >10kg

***Check lower limb perfusion after cannulation of femoral vessels*

- CENTRAL Lines
  Single lumen (leadercath)

Preterm neonate	<2kg	22G 4 cm
Term neonate	2-4kg	20G 8 cm
Child		20G, 18G, 8 cm

Double lumen

0-6 months	< 10 kg	4Fr, 5cm

Triple lumen

0-6 months	<10kg	4.5Fr,6cm
6 months - 12yrs	10-40kg	5.5Fr, 5cm, 8cm, 13cm
>12yrs	>40kg	7Fr, 16cm

CATHETER/VEIN SCALE

Chart for determining catheter size/length versus appropriate vein diameter and depth from ultrasound assessment

Peripheral vascular access devices — PICC Excellence, Inc.

FRENCH SIZE	2	2.5	3	3.5	4	4.5	5	5.5	6	7	8
CATHETER GAUGE SIZE	24	22	20	19	18	17	16	15	14		12
CATHETER MEASUREMENT mm	0.55	0.75	0.9	1.06	1.27	1.47	1.65	1.8	2.1	2.3	2.7
INCHES	0.022	0.026	0.0355	0.042	0.05	0.058	0.065	0.072	0.083	0.092	0.105
VESSEL SIZE needed 1/3 vs 2/3 catheter to blood flow. French size is desired vein size	2mm	2.5mm	3mm	3.5mm	4mm	4.5mm	5mm	5.5mm	6mm	7mm	8mm

INS RECOMMENDATION for 2/3 catheter in vein

DEPTH using 45 degrees	0..25	0.5	.75	1.0	1.25	1.5
CATHETER LENGTH needed	1.2cm	2cm	3.2cm	4.25cm	5.25	6.4cm
DEPTH using 30 degrees	0.25	0.5	.75	1.0	1.25	1.5
CATHETER LENGTH needed	1.5cm	3cm	4.5cm	6cm	7.5cm	8cm

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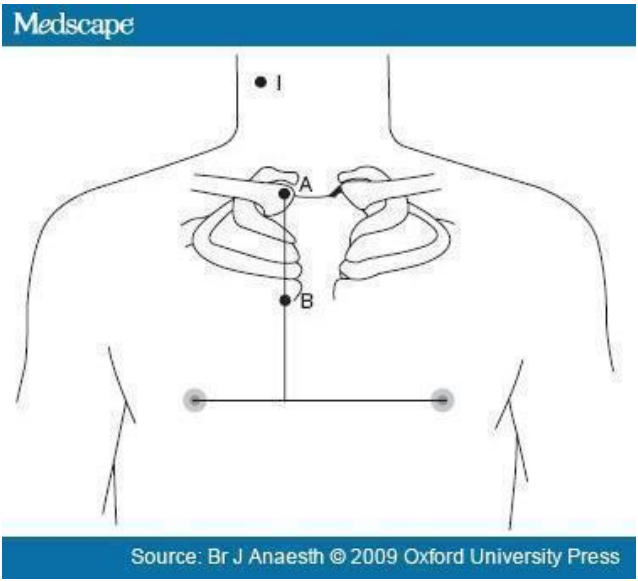
Method for determining insertion depth of CVL



CVL tip should be positioned at the junction of SVC & RA; level of carina on CXR.

Two points are marked on the patient's skin during the IJV catheterization. Point A is marked at the sternal head of the right clavicle, the most prominent point. Point B is marked at the midpoint of the perpendicular line from Point A to the line connecting both nipples. Point I is the insertion point of the needle. Distance from Point I to Point A and from Point A to Point B is measured. The depth of CVC is

determined by adding the two measurements and subtracting 0.5 cm from this.

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