Review articles

The use of extraglottic airway devices in diving medicine – a review of the literature. Part 2: Airway management in a diving bell and deck decompression chamber

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Key words
Extraglottic airway devices, resuscitation, first aid, bell diving, disabled diver, medical kits, review article

Abstract

(Acott CJ. The use of extraglottic airway devices in diving medicine – a review of the literature. Part 2: Airway management in a diving bell and deck decompression chamber. *Diving and Hyperbaric Medicine*. 2007; 37: 16-24.)
Airway management and resuscitation in a diving bell (DB) or deck decompression chamber (DDC) are difficult due to the confined space, limited lighting and limited equipment. A review of currently available extraglottic airway devices was undertaken to determine which ones would be suitable for acute airway management in a DB or DDC. The review concentrated on ease of insertion and use, training required, protection against aspiration and gastric inflation, suitability for rescue breathing (RB) and spontaneous ventilation. The ones deemed suitable were then tested in a hyperbaric environment. Naspharyngeal or oropharyngeal airways, the classic laryngeal mask airway and the streamlined liner of the pharyngeal airway (SLIPA™) were found to be suitable for use in the DB or DDC. However, more data for the efficacy of the SLIPA™ in resuscitation or airway management of trauma is required.

Introduction

Airway management and resuscitation in a diving bell (DB, Figure 1) or deck decompression chamber (DDC) are difficult due to the confined space, limited lighting and rudimentary equipment.[1] A Medline search revealed that there are no recent case histories or data about emergency airway management or management of an unconscious diver in a DB or DDC, the only previous study being from 1981.[2] This issue is also not addressed in recent editions of the US Navy or National Oceanographic and Atmospheric Administration diving manuals.

Retrieval of the unconscious diver into the DB requires the use of a pulley system (Figures 2a and b). Once inside, the bell space limitations dictate that any resuscitative efforts are confined to the patient (diver) suspended in the upright position by the pulley system or lying upright against the side of the bell (Figures 3a to d).[1,3] Cardiopulmonary resuscitation (CPR) inside a DB is, therefore, extremely hard if not impossible to do. The procedure manual for the Comex Company recommends the insertion of an oropharyngeal airway (OPA) and the use of a cervical collar to stabilize the head. Rescue breathing (RB) with the patient upright suspended by a pulley or against the side of the bell would be difficult because the resuscitator is facing the patient. External cardiac compression (ECC) with the patient upright lying against the side of the bell could be performed with the resuscitator's hands but when the patient is suspended by the pulley the resuscitator is required to use his knee or head.[3] ECC in these positions would be ineffective considering that only between 5 and 20% of normal cardiac output can be achieved with the patient supine on a flat, hard surface.[4] Effective CPR can be performed inside a DDC because the patient is flat on a hard surface; however, the position of the resuscitator(s) relative to the patient is dependent on the size and shape of the chamber. Prevention of gastric aspiration in a DDC or DB is difficult. The risk, however, may be diminished in a DB because the patient is in the upright position.

Current airway management recommendations include the use of a Guedel or Brook airway, cervical collar, Laerdal pocket mask (LPM), a wooden screw (to be placed between the teeth if trismus is present) and a hand- or foot-operated suction.[3,5] The clinical circumstances (presence of trismus, available space, retrieval position of the patient) dictate the appropriate extraglottic airway device (EAD) to be used.

The Diving Medical Advisory Committee (DMAC, United Kingdom) suggested that the classic laryngeal mask airway (cLMA), size not specified, should be available if the diving medical technician is trained to use one.[5] The use of all cuffed EADs requires specialised care in a pressurised environment. Pressurisation will decrease the volume of the cuff, making it difficult to reinflate (Boyles' and Laplace's Laws), while during decompression it will expand necessitating the measurement of the intra-cuff pressure. The cuff volume/pressure will also change with gas diffusion as the gas mixtures breathed and chamber atmosphere change. The majority of these problems are overcome if water is added to the cuff prior to pressurisation. However, even if

Figure 1
Schematic of diving bell; note the hoist dangling through the bottom entry hatch

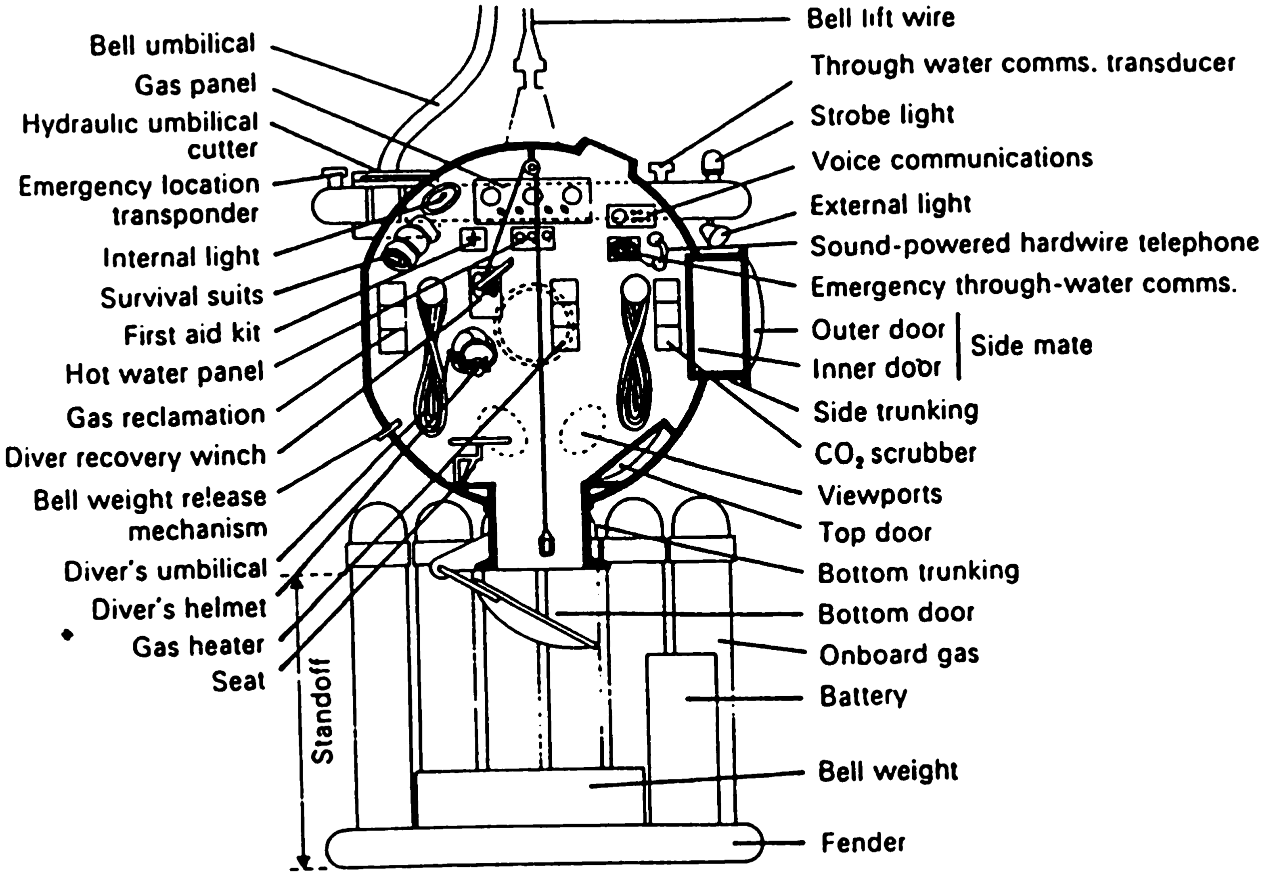
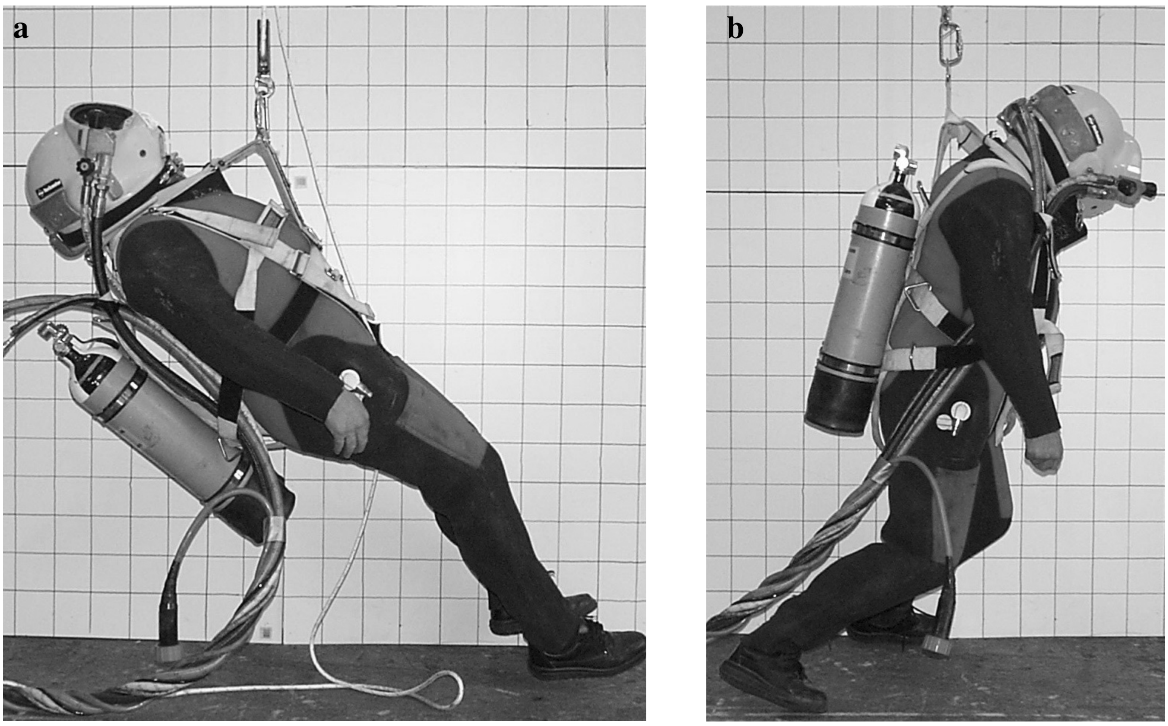


Figure 2
The diver may be lifted into the bell with the hoist attached either anteriorly (a) or posteriorly (b). This is often assisted by partial flooding of the bell to help float the diver through the hatch.



the cuff is filled with water the intra-cuff pressure will need to be monitored during decompression because not all air pockets will be completely eliminated. The DMAC made no recommendation concerning the management of the cLMA's cuff during compression or decompression.[5]

A study published in 2000 concerning simulated airway management during spaceflight has some implications for the management of the airway and unconscious diver in a DB or DDC because the space capsule has similar space and lighting limitations.[6] This study showed that intubation was difficult, while the cuffed oropharyngeal airway (COPA), cLMA or intubating LMA (iLMA) can be used successfully.[7] The COPA is no longer available. Limitations of the iLMA were discussed in the first part of this review article.[7]

DMAC specified that intubation equipment is to be at the dive site but not in the chamber.[5] Intubation is an acquired skill and retraining is necessary for skill retention. Therefore, it may be inappropriate for on-site personnel (including medical practitioners) to attempt if they rarely practise it. The aim of this paper was to decide which of the currently available EADs (listed in Table 1 of Part 1 of this review[7]) are suitable for emergency airway control in a DB or DDC using the criteria outlined in the left-hand column of Table 1 overleaf. The airway devices thought to be suitable were then tested in a hyperbaric environment. The majority of the available EADs are reviewed in Part 1 of this paper except oropharyngeal (OPA) and nasopharyngeal (NPA) airways and the Laerdal pocket mask, which are reviewed here.[7]

Literature review

OROPHARYNGEAL AIRWAYS (OPAs)

Guedel oropharyngeal airway (Figure 4)

The Guedel airway has a flange at the oral external end, a reinforced straight bite area (which fits between the victim's teeth) and a curved intraoral air channel, which follows the

Figure 3
The recovered diver partially (a and b) inside the bell with the bell-man maintaining the airway with the anterior and posterior hoist positions. In (c) the bell-man is barely visible behind the diver as he is hoisted into the bell.

Figure 4
The Guedel oropharyngeal airway consists of three portions: the flange, the bite portion and the oral air channel; designed by Arthur Guedel in 1933, it is still the most used airway aid

contour of the tongue. It is manufactured in plastic in various sizes for paediatric and adult use. It is inserted easily and can be used in either spontaneously breathing patients or those requiring RB or bag mask ventilation (BMV).[8]

Brook airway (not shown)

The Brook airway was designed in 1962 to make RB "less unpleasant to perform".[9] It consists of a Guedel-shaped intraoral section, which is connected to a flange designed to maintain an airtight fit on the victim's mouth. There is an extraoral ventilating tube, which contains a one-way valve allowing the victim's expired air to exit through a short side arm. It is made of plastic and is easily inserted with the operator facing or behind the patient. The victim's jaw needs to be supported as with a Guedel airway. There are two sizes available – one for use in children aged less than 9 years with an intraoral section 4 cm in length, and the other for adult use 9 cm in length. Supplemental oxygen cannot be given.

Glossopalatine tube (Lifeway) airway (Figure 5)

The glossopalatine tube (Lifeway) airway is a variant of the Brook airway but has a side port for supplemental oxygen. It consists of a mouthpiece or 15 mm connector for the rescuer, a tube containing a non-rebreathing valve, a mouth sealing cap and an intraoral glossopalatine tube that can be tilted to displace the tongue from the posterior pharyngeal wall. The intraoral tube now has additional side holes to aid ventilation.[10] Complications associated with the use of an OPA are listed in Table 2.[8,11–13]

NASOPHARYNGEAL AIRWAY (Figure 6)

A nasopharyngeal airway (NPA) is the only EAD that can be used if the victim's mouth cannot be opened. It is a plastic tube designed to fit the curvature of the nasopharynx with a flange at the nasal end and a bevelled distal pharyngeal end. A safety pin is often used in the nasal end to prevent the disappearance of the NPA into the nose. It avoids dental damage and is better tolerated by a semi-conscious patient than are oral airways. Several sizes are available.[8]

Table 1
The desired characteristics of extraglottic airway devices (EADs) for use in a diving bell or deck decompression chamber and a comparison of nasopharyngeal and oropharyngeal airways, and the cLMA, SLIPA and COBRA EADs (LRT – lower respiratory tract; Nd – no data; Ld – limited data)

Characteristic	NPA	Guedel	Brook	Lifeway	cLMA	SLIPA™	COBRA
Simple to use	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Easily inserted	Yes	Yes	Yes	Yes	Yes	Ld	+/-
Easily stored	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Low resistance	+/-	+/-	+/-	+/-	Ld	Nd	Nd
Protects LRT	No	No	No	No	+/-	Ld	No
Stable once inserted	Yes	+/-	Yes	Yes	+/-	Yes	+/-
Cuffless	Yes	Yes	Yes	Yes	No	Yes	No
CPR friendly	Yes	Yes	Yes	Yes	Yes	Nd	Ld
Ease of training	Yes	Yes	Yes	Yes	Yes	Ld	Ld
Prevents aspiration	No	No	No	No	No	+/-	No
Prevents gastric inflation	No	No	No	No	No	Yes	No
Atraumatic insertion	+/-	Yes	Yes	Yes	Yes	+/-	Yes
Useful in trismus	Yes	No	No	No	No	No	No
Various sizes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Few complications	Yes	Yes	Yes	Yes	Yes	Nd	Nd

When correctly positioned, the NPA extends from the nares to end just above the epiglottis. In a study of 120 patients, there was no correlation between length of NPA needed and the victim's height and weight.[14] Interestingly, the majority of commercially available NPAs were too short. Other authors recommend that the length of NPA required approximates to the distance from the tip of the nose to the tragus of the ear plus 2.5 cm.[8] The complications noted with the use of NPAs are listed in Table 2.[8,15,16] The majority of these can be avoided by correct insertion technique:

1 Lubricate the airway
2 Select the patient's most patent nostril
3 Insert gently perpendicular to the face so that it will pass along the floor of the nostril
4 Force must not be applied if resistance is felt
5 To reduce trauma, rotation of the NPA 90° so that the bevel is in a posterior position has been recommended; this position is maintained until resistance is lost as it enters the nasopharynx
6 Rotate the NPA back 90°.

Contra-indications to the use of an NPA include nasal and base-of-skull fractures and, in the clinical setting, choanal atresia, anticoagulation medication and previous cleft-lip surgery.[8,16]

Figure 5
The glossopalatine (Lifeway) airway is similar to the Brook airway but has the advantage of allowing supplementary oxygen through the side port

LAERDAL POCKET MASK (Figure 7)

The Laerdal pocket mask (LPM) can be used for RB if the rescuer is situated near the victim's head. It requires jaw support and/or the use of an NPA or Guedel airway. One-rescuer use in a DB or DDC would require it to be repositioned each time RB is attempted. Therefore, it is not recommended for use in a DB but can be used in a DDC if there are two rescuers. The cuff needs to be filled with water prior to compression to maintain its integrity in a pressurised environment.

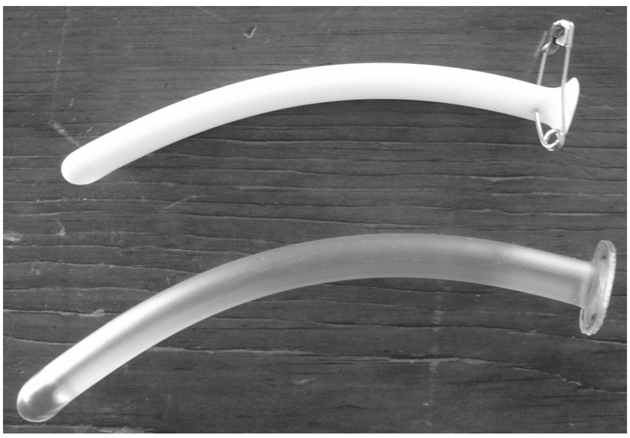
OTHER EADs

The cLMA has been extensively described.[1,17] The main advantages and disadvantages of the cLMA for use in a DDC or DB are listed in Table 3. The physical characteristics of commercial divers (working in the North Sea) indicate that sizes 4 and 5 are adequate.[2] The cuff needs to be filled with water prior to compression to overcome compression/decompression problems.

Aspiration risks are decreased if the ProSeal laryngeal mask airway (pLMA) or the streamlined liner of the pharyngeal airway (SLIPA™, Figure 8) is used.[18,19] The SLIPA™ is designed to seal the airway without the use of an inflatable cuff and its design may prevent aspiration. A study showed that it compares favourably with the cLMA in ease of insertion.[18] At present it is not readily available and more studies are needed. The pLMA will also allow stomach decompression but studies have shown it to be more difficult to insert when compared with the cLMA, and so it is not suitable for use in this situation.[19]

The oesophageal tracheal combitube (OTC) is a double-lumen, double-cuffed, polyvinyl extraglottic airway device.[1,20] It is easily inserted but not easily stored because of its large size,

Figure 6
Two types of nasopharngeal airway (NPA) are shown. The NPA passes through the nose and extends to just above the epiglottis; the flange rests outside the nostril and in some cases has a safety pin passed through it



and its two cuffs make its use in a DDC or DB limited. It may be used as a substitute for intubation at the dive site.

Results of literature search

The suitability of, or the reasons for rejecting, a particular EAD are listed in Table 4. No EAD satisfied all the criteria stipulated in the left-hand column of Table 1. The cLMA (Figure 1, Acott 2006[7]), SLIPA™ (Figure 8), COBRA (Figure 9), Brook (not shown) and Lifeway (Figure 5) airways were thought to be suitable for use because of

- ease of insertion
- ease of training
- the exterior airway tube would make RB possible from any position.

The cLMA and COBRA rely on inflated cuffs to seal the airway and therefore would need water added to the cuff to avoid the problems of a pressurised environment. A lack of space and manoeuvrability would make the Guedel and NPA unsuitable for RB and useful only if the victim was unconscious but breathing. The NPA is the only airway suitable in cases of trismus (Table 1 compares these devices).

Further testing was needed to confirm the suitability of the cLMA, SLIPA™ and COBRA in a pressurised environment.

Methods

The cLMA, COBRA and SLIPA™ were pressurised to 405 kPa (4 ATA) and the following tests performed:

1. 20 ml of water was placed in the cuff of a cLMA and COBRA after full deflation and then both were compressed and decompressed.
2. A cLMA and COBRA were compressed without any additional air placed in their cuffs and then the cuffs were inflated at depth.

Figure 7
The Laerdal pocket mask is collapsible and can be used either in rescue breathing or attached to a ventilating bag

Table 2
Complications of nasopharyngeal and oropharyngeal airways

Oropharyngeal

- Uvula damage (by entrapment of the uvula between the oral airway and the hard palate)
- Lip and tooth damage
- Tongue ulceration and necrosis from prolonged use
- Gastric inflation
- Worsening of or causing an obstruction (if it is too large the tip can displace the epiglottis posteriorly or if too small it will push the tongue into the posterior pharynx obstructing the airway)
- Fracturing of the airway with subsequent dislocation into either the oesophagus or the lungs
- Attempted use in a semi-conscious patient with intact airway reflexes causing gagging and/or vomiting leading to airway obstruction and/or aspiration

Nasopharyngeal

- A reported rate of epistaxis of 3–20% (with or without aspiration of blood)
- Sub-mucosal passage
- Turbinate damage
- Disappearance into the nose
- Induced vomiting with or without aspiration
- Induced laryngospasm (if too long)
- Naso-oesophageal intubation (if too long)
- Gastric inflation with rescue breathing
- Perforation of the cribriform plate (although cranial vault penetration has been reported only with nasotracheal intubation and nasogastric tube insertion)
- Obstruction from dried secretions, blood or compression within the nasal cavity

Table 3
Advantages and disadvantages of the cLMA for use in a diving bell or deck decompression chamber

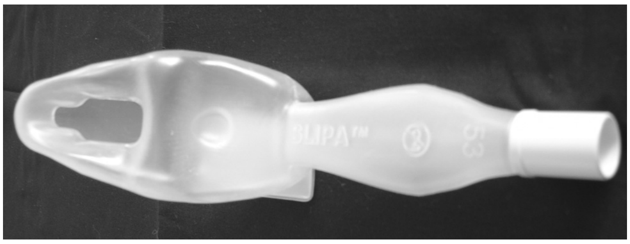
Advantages

- Small and easily stored
- Can be inserted blindly
- Insertion is anatomically independent
- Insertion may not be impeded by manual inline immobilisation or the presence of a hard collar
- Rescue breathing is easier

Disadvantages

- Does not protect the airway from aspiration even though it offers better protection than OPAs or NPAs
- Risk of gastric inflation with rescue breathing
- Difficulty with insertion if the patient's head is in the neutral position or if the patient is in the upright position facing the operator
- Inflatable cuff
- An over-inflated cuff will interfere with the airway seal causing a gas leak with rescue breathing and subsequent gastric inflation

Figure 8
The SLIPA™ airway

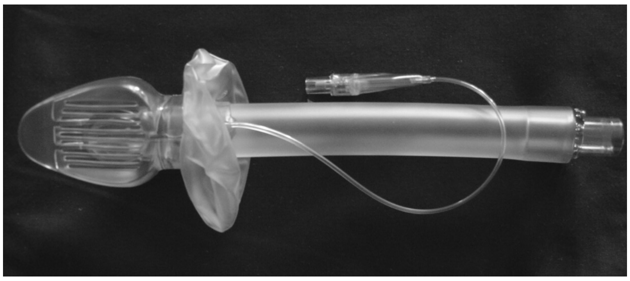


3 The SLIPA™ was used with a manikin to see if ease of insertion changed at pressure.
4 The ease of insertion of the cLMA and COBRA with 20 ml of water in their cuffs was tested on a manikin.
5 At atmospheric pressure, 20 ml of water was again placed in the cuffs of a cLMA and COBRA after full deflation and then both were tested for ease of insertion in a manikin to eliminate any deterioration in performance by the operator due to nitrogen narcosis at depth.

Results

Insertion of the COBRA with the cuff inflated with 20 ml of water was not possible in either attempt (at atmospheric or increased pressure) and during insertion the cuff ruptured. Difficulty with insertion was found even with decreasing volumes of water (15 and 10 ml). In addition, if the cuff was

Figure 9
The COBRA airway; the grilled section that fits over the laryngeal inlet is clearly shown. It is impossible to insert the COBRA with the cuff inflated with 20 ml of air or water.



inflated at depth it distorted and ruptured during ascent if the pressure/volume was not monitored. These tests indicated that the COBRA functioned poorly and therefore it was eliminated.

Insertion of the cLMA was possible at either atmospheric or increased pressure with 20 ml of water in the cuff. If the cuff of the cLMA was inflated at pressure the cuff overinflated and distorted the anatomy of the mask during the ascent. There was no distortion of the cuff during ascent if it was filled with 20 ml of water prior to pressurisation.

Pressurisation did not alter the stiffness or insertion characteristics of the SLIPA™.

Table 4
Results of a literature review of the suitability of extraglottic airway devices for use in a diving bell or deck decompression chamber (Y – yes; N – no)

Extraglottic airway device	Suitable?	Comments
Oropharyngeal airways	Y	
Nasopharyngeal airway	Y	
Laerdal pocket mask	Y	
Classic laryngeal mask airway	Y	
Streamlined liner of the pharyngeal airway	Y	More data needed
ProSeal laryngeal mask airway	Y	Suitable for use at a diving platform
Oesophageal tracheal combitube	Y	Suitable for use at a diving platform
Easy tube	Y	Suitable for use at a diving platform; not readily available
COBRA perilaryngeal airway	N	Found unsuitable following testing
Intubating laryngeal mask airway	N	Cannot be left in for long period of time
Pharyngeo-tracheal lumen airway	N	Not readily available
Cuffed oral pharyngeal airway	N	No longer available
Glottic aperture seal airway	N	Not readily available, introducer required, not easily inserted
Laryngeal tube airway	N	Two cuffs, limited data
Airway management device	N	Two cuffs, limited data
Soft seal laryngeal mask	N	Not easily inserted
Laryngeal tube suction airway	N	Two cuffs, limited data
PAxpress oropharyngeal airway	N	Traumatic, limited data

Discussion

All of the recommended EADs (OPA, NPA or cLMA) can be readily used in a DB or a DDC because they are easily inserted. Insertion of an OPA or an NPA requires minimal training but the period of time before retraining is required is unknown compared with 6 and 12 months for the cLMA.[21]

The Guedel airway and an NPA are useful only if the victim is unconscious but breathing in a DB, while the LPM and all the OPAs and NPAs can be used by two rescuers performing CPR in a DDC.

Although not ideal, the cLMA could be used in nearly all situations in a DB or DDC except where the victim is semi-conscious and intolerant of an OPA or has trismus; in these situations an NPA is the EAD of choice. Additional training is required for the use of a cLMA and a simple protocol relating to the management of the cuff during compression and decompression needs to be adhered to:

1 Aspirate all air from cuff prior to compression
2 Fill cuff with 20 ml of water
3 Following insertion, check airway seal by applying gentle positive pressure and then add additional water if necessary (10–20 ml will be required for sizes 4 and 5 respectively)
4 During decompression, repeatedly aspirate for air every 405 kPa (4 ATA) decrease in pressure.

Several EADs can be used on the dive platform at atmospheric pressure. The OTC and pLMA are alternatives to intubation if the resuscitator has limited training in endotracheal intubation but studies suggest the OTC is the easier to insert of the two.[7]

Table 5
Suggested airway devices suitable for use in a diving bell (DB), deck decompression chamber (DDC) or on a diving platform

Diving bell
- Nasopharyngeal airways sizes 7, 7.5, 8
- Brook airway or glossopalatine tube airway
- Classic laryngeal mask with 20 ml syringe (sizes 4, 5)
- Cervical collar
- Hand-operated suction

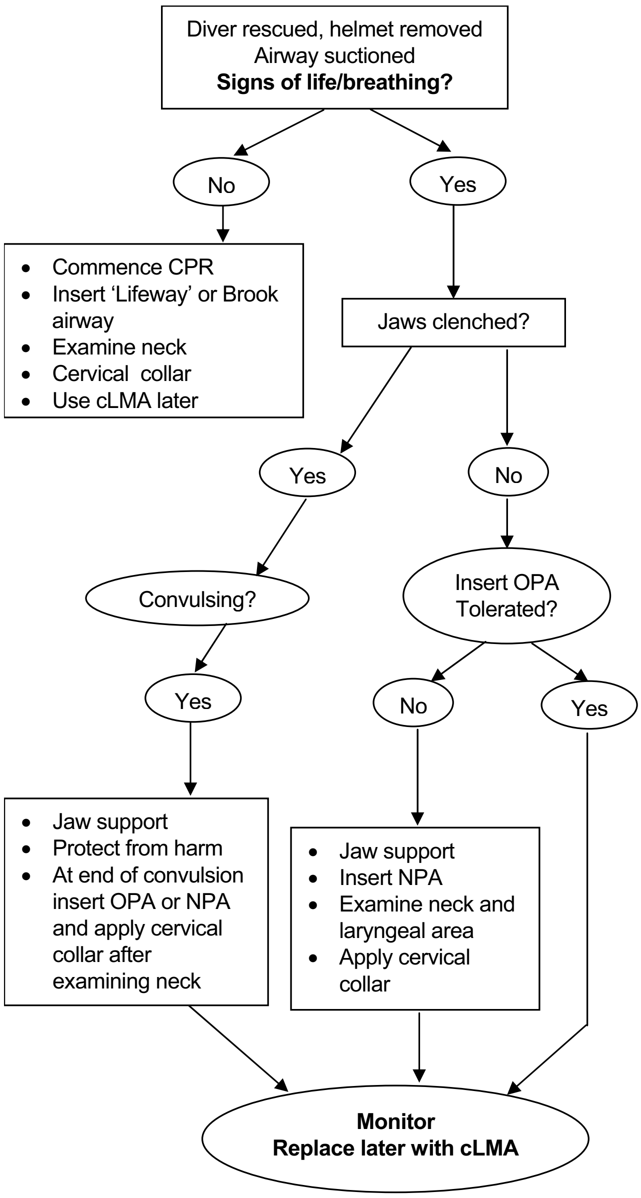
Deck decompression chamber
- As for DB
- Guedel airway
- Laerdal pocket mask

Diving platform
- As for DDC but better suction
- Oesophageal tracheal combitube
- ProSeal laryngeal mask airway (digital insertion plus introducer)

Summary

None of the EADs reviewed is ideal. Circumstances may dictate the choice of EAD to be used. The cLMA could be used in nearly all situations but additional training/retraining is required. The currently recommended interval for retraining of diving medical technicians (every three years) is not adequate for skill retention in the use of the cLMA. An annual refresher (manikin training) on the use of the cLMA is required. An airway/resuscitation management protocol for use in a DB is outlined in Figure 10, while Table 5 lists a range of suggested airway equipment that should be available in a DB, in a DDC, or at a diving platform.

Figure 10
Flow chart for airway management in a diving bell



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