HUNG'S DIFFICULT AND FAILED AIRWAY MANAGEMENT

THIRD EDITION

ORLANDO R. HUNG • MICHAEL F. MURPHY

ASSOCIATE EDITORS

Thomas J. Coonan • Narasimhan Jagannathan • George Kovacs

J. Adam Law • Ian R. Morris • Ronald D. Stewart

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NOTICE

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DEDICATION

We would like to thank our families for their understanding and support of our academic and clinical work by dedicating this edition to: Jeanette, Christopher, David, and Ana Hung and to Debbi, Amanda, Ryan, and Teddy Murphy. We also dedicate this edition to the tireless efforts of all who teach airway management. We are grateful for their commitment to the prevention of death and disability related to airway management failure.

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FOREWORD

Although the practice of anesthesia professionals and others who do airway management is full of unexpected challenges, perhaps nothing strikes more fear in our hearts than a patient with a difficult airway. Unlike other events, which may be limited to certain narrow sub-specialties, challenging airway management occurs across nearly all domains of patient care, all patient ages, and many sites of care such as perioperative, emergency department, ward settings, as well as in unusual sites such as pre-hospital or combat casualty care. Hence, books such as this are vital as contextual compilations of up-to-date information on approaches and techniques for the myriad needs of patients for oxygenation and ventilation. Most simply put, the most fundamental goal of airway management is to accomplish what for most patients is routine, but for some is so elusive, which is—as one of my supervising attending and later faculty colleague (Mervyn Maze) put it years ago, to "get some green gas in the right hole [U.S. oxygen color code is green]." This spirit is exemplified in the modern evolution from the notion of "can't intubate, can't ventilate" to "can't intubate, can't oxygenate" emphasizing that oxygenation comes first with ventilation as important, but still secondary.

As noted in the Preface, the third edition of this book contains some important new information and new chapters. I am particularly pleased by the addition of a chapter on human factors and airway management. Over the last few decades we have collectively recognized that all the clinical knowledge or technical dexterity in the world can come to no avail without appropriate design and use of equipment, systems, processes, and teamwork. Another key tenet of human factors is the importance of cognitive scientist Don Norman's concept of putting "knowledge in the world" rather than just relying on "knowledge in the head." The creation of a variety of standard protocols for airway management, and their representation in various graphical cognitive aids, is now a well-accepted and critical aspect of modern airway management preparation and execution. Thus, the chapter on the algorithms that describes and compares the many different protocols, mnemonics, and graphics is particularly useful. No one protocol will suit all clinicians and all sites so knowing their individual strengths and weaknesses is important.

A particular strength of this book is the numerous descriptions of airway management alternatives and their pros and cons in a wide variety of specific clinical situations. This is based on the concept—described in its own chapter—of context-sensitive airway management; this ties in very strongly with human factors and algorithms because every situation is indeed different. The approach of high-reliability organizations is to standardize where possible, but to remain flexible and resilient as circumstances demand. Even for readers who do not usually work in some of the settings described, the well-articulated synthesis of the processes of airway assessment, evaluation of the overall situation, and choice of options will help everyone to hone their decision-making skills whatever their usual setting.

In fact, these case discussions are a simple form of "simulation" by storytelling—as clinicians hear or read of a colleague's tough case, they simulate in their own heads what they would think or do in a similar situation. Such case studies thus naturally dovetail with the chapter on the use of simulation to teach, practice, and hone skills of airway management—with simulation techniques ranging from simple procedural task trainers to full-blown interprofessional mannequin-based simulations.

This book has already stood the test of time, but the third edition offers a fully modern view of the complexities and nuances of this life-threatening and life-saving arena of clinical care. The authors, contributors, and I share the hope that through the knowledge, skills, attitudes, and behaviors conveyed by this book the rightful fear of the difficult airway will be surmounted by mastery and expertise, leading to the preservation or rescue of uncounted hearts, brains, and lives.

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PREFACE

Since the last edition of our textbook, strategies and guidelines in managing the difficult and failed airway from the American Society of Anesthesiologists, the Canadian Airway Focus Group, the Difficult Airway Society in the United Kingdom, and other organizations have been updated and revised using the currently available evidence. These revised recommendations for the management of the difficult and failed airway are reflected in all chapters of this edition of the textbook including the new chapters. For example, two chapters (Chapters 6 and 34) were added to this edition to address "human factors" as they relate to the stresses and strains of difficult and failed airway management. The Difficult Airway Society guidelines specifically acknowledge the importance of human factors in crisis resource management. Interpreted in context, the application of the four basic methods of oxygenation (bag-mask-ventilation, use of extraglottic devices, tracheal intubation, and front of neck access) remains the most logical approach for managing a failed airway. Furthermore, the National Audit Project 4 (NAP4) and other studies have consistently identified difficulties associated with needle (Seldinger technique) cricothyrotomy such that it has become clear that when faced with a "cannot intubate, cannot oxygenate" (CICO) situation, surgical (open) cricothyrotomies are much more successful than needle or Seldinger cricothyrotomies. Many chapters of this edition emphasized the importance of early front of neck access using open cricothyrotomy in the adult population.

This edition is divided into ten sections: the first section consists of the foundational information in airway management; the second section reviews airway devices and techniques; the third to the ninth sections discuss airway management in different clinical settings, including prehospital care, in the Emergency Department, the Intensive Care Unit, the operating room, the Post Anesthetic Care Unit, as well as other parts of the hospital; and the last section highlights practical issues in airway management. A number of new chapters and clinical cases have been added to this new edition. As indicated above, two chapters have been added to discuss human factors in airway management. To avoid confusion related to "front of neck" access, a tracheotomy chapter has been added to this edition. In addition, chapters discussing the management of patients with the aspiration of gastric contents, obstructive sleep apnea, tracheal stenosis requiring jet-ventilation, and airway management under combat conditions have been added to this edition.

Videos depicting all airway management techniques are available at **http://DifficultAirwayVideos.com**. Bag mask ventilation, topical anesthesia of the upper airway, and open cricothyrotomy videos have been added to this edition.

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Orlando Hung, MD, FRCP(C)
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SECTION 1

PRINCIPLES OF AIRWAY MANAGEMENT

CHAPTER 1

Evaluation of the Airway

Michael F. Murphy and Johannes M. Huitink

INTRODUCTION

"Airway management" may be defined as the application of therapeutic interventions that are intended to effect gas exchange in patients who are unable to do it for themselves. *Gas exchange* is fundamental to this definition.[1] A number of devices and techniques are commonly employed in health care settings to achieve this goal. These include the use of bag-mask-ventilation (BMV), extraglottic devices (EGDs), oral or nasal endotracheal intubation (ETI), and invasive or surgical airway techniques.

The failure to adequately manage the airway has been identified as a major factor leading to poor outcomes in anesthesia, critical care, emergency medicine, hospital medicine, and emergency medical services (EMS).[2,3] Adverse respiratory events constituted the largest single cause of injury in the ASA Closed Claims Project.[4] The 4th National Audit Project (NAP4) conducted in the United Kingdom over a 1-year period of time identified major airway management complications in the operating room (OR), critical care units, and emergency departments leading to death, brain damage, emergency surgical airway, or unexpected ICU admission.[5,6] NAP4 reinforced the findings of the National Reporting and Learning System in the United Kingdom that found 18% of 1085 airway management complications in ICU over a 2-year period (2005 to 2007) were directly related to the act of intubation.[7]

It is critically important to recognize that the single most important factor leading to a failed airway is the failure to predict the difficult airway.[3,4,8] Other factors that can make airway management challenging are human factors as described in Chapter 6. Screening tests intended to predict difficult or impossible BMV and laryngoscopic intubation are unable to predict success or failure with any degree of certainty in otherwise normal patients. For this reason, the terms "reassuring" and "non-reassuring" have been coined to describe one's summative assessment of the various operations associated with airway management (e.g., BMV, EGD, laryngoscopy and intubation, and surgical airway).[9] It is because of this "reliability gap" that airway practitioners need to be prepared to manage an airway predicted to be difficult appropriately (e.g., awake technique) and to resort to surgical airway management in the event that nonsurgical techniques fail.[9-11]

The fundamental dilemma facing the airway practitioner is to predict if the airway is "reassuring" or "non-reassuring." The task is to identify non-challenging versus challenging airways employing tools with poor predictive value alone and in combination. As mentioned above, theASA Guidelines have used the terms "reassuring" and "non-reassuring." Huitink and Bouwman[12] have recently advanced the proposition that a trained practitioner should be able to manage a patient with a reassuring airway (they use the term "basic airway") employing basic airway management techniques (BMV and ETI) after proper training. Even more advanced airway rescue techniques (e.g., EGD) in these patients are expected to be relatively easy because the anatomy is normal. Conversely, they maintain that the less reassuring the airway, the greater the need to prepare for failure. A very common sense approach!

This chapter deals with the identification of the difficult and failed airway, particularly in an emergency, in which case evaluation and management must be done concurrently in a compressed time frame and canceling the case or delaying airway management is not an option.

Successful airway management is generally governed by four intertwined factors that constitute the "context" in which that airway is managed (see Chapter 7):

- A clinical situation of varying urgency, venue, and resources
- Patient factors including airway anatomy and vital organ system reserve
- Available airway resources
- Skills of the airway practitioner

Because the airway practitioner must choose a method of airway management from an array of techniques, precision of language and communication is essential. Success or failure to effect gas exchange in an apneic patient may occur with any single method:

- Bag-mask-ventilation
- Extraglottic device ventilation
- Direct laryngoscopy or DL (e.g., straight or curved laryngoscope blades)
- Indirect laryngoscopy (e.g., video-laryngoscopy [VL], flexible endoscopy)
- Emergency oxygenation and ventilation techniques (e.g., Ventrain™ or Manujet™)
- Invasive surgical airway (e.g., cricothyrotomy)

Airway practitioner may find any of these methods "difficult," and difficulty with one does not necessarily indicate that another will be difficult though there tends to be a relationship.[13,14] Strategies to identify difficult BMV, difficult ventilation employing an LMA, difficult DL and intubation, difficult VL, and difficult surgical airway will identify predictors unique to the method (e.g., surgical airway would be difficult in a patient with an anterior neck hematoma or tumor mass), and predictors associated with some of the other methods (e.g., male sex) or all of the other methods (e.g., history of neck and upper airway radiation therapy or the application of cricoid pressure). This expands on the definition of *difficult* as promulgated by the American Society of Anesthesiologists (ASA) beyond difficult BMV and intubation to include the complete array of methods that may be employed to manage an airway.[10]

Any method may fail in which case the terminology "failed BMV," "failed ETI," or "failed EGD" may be employed. Conventionally, if all of these methods fail the airway is called a "failed airway," and is equated with a "cannot intubate, cannot oxygenate" (CICO) airway.[11] In the past, this situation has been called "cannot intubate, cannot ventilate" (CICV), though CICO is more accurate and currently more commonly employed.

For more clarity, a failed intubation defined narrowly as the failure to intubate the trachea on three attempts[9,15] (the DAS 2015 Guidelines permit one additional attempt by an expert: 3+1)[11] may not constitute a failed airway if one is able to affect gas exchange with BMV or with an EGD. However, *intubation failure* ought to conjure a sense of urgency and mandates the airway practitioner to rapidly switch to a failed airway management sequence or drill because such a situation may become life-threatening if gas exchange cannot be provided expeditiously and adequately by other means. Furthermore, the alternative airway technique employed must have the highest degree of success in the practitioner's skill set. It is inappropriate to make random disorganized attempts to manage the airway in the hope that one of the airway techniques might work. Rather, one should have a planned strategy (see the algorithms in Chapter 2) including invasive techniques such as cricothyrotomy.[11,16,17]

Caveat:

> Failure to Evaluate the Airway and Predict Difficulty is the Single Most Important Factor Leading to a Failed Airway.
> (*ASA Closed Claims Database*)[4]

This assumes that the practitioner acts on the prediction and selects the most appropriate technique.

INCIDENCE OF DIFFICULT AND FAILED AIRWAY

How Common Are the Difficult and Failed Airway?

Bag-mask-ventilation, the use of EGDs, ETI, and surgical airway management constitute the four primary avenues by which gas exchange is provided in the event patients are unable to do so adequately for themselves. In each category, difficulty and failure may be encountered. Failure of all four, ordinarily, leads to death or brain damage.

Until recently, the success or failure of airway management has been defined in terms of BMV and orotracheal intubation. The introduction of EGDs and the heightened profile of cricothyrotomy have broadened such concepts. Fortunately, tracheal intubation is usually straightforward, particularly in the elective setting of the OR, though it should be realized that tracheal intubation can be performed in many different ways with direct or indirect techniques and each technique has its own complication and failure rates. The same cannot be said for venues outside of the OR where airways are often anything but "straightforward."

Airways that are difficult to manage are fairly common in anesthesia, emergency medicine, critical care, and EMS practice, with some estimates as high as 20% of all emergency intubations.[9-12,18-21] However, the incidence of intubation failure is quite uncommon (ranging 0.5% to 2.5%), and the disastrous situation of being unable to intubate or ventilate rarely occurs (0.1% to 0.05%).[2,18-26] This translates to a "can't intubate, can't oxygenate" failure rate of about 1:1000 to 1:2000 patients in a general surgical population. The incidence is strikingly higher in the parturient undergoing cesarean section (1:280), an almost tenfold increase.[27-29] Further, the gold standard awake flexible bronchoscopic intubation also has a defined failure rate as high as 13%.[30]

How Do We Avoid Airway Management Failure?

Although circumstances can vary widely, the expectation is the same: timely, effective airway management executed without patient injury. In circumstances of multiple trauma, facial or airway swelling, abnormal upper airway anatomy, upper airway hemorrhage, or a myriad of other difficult airway scenarios, intubation may be difficult, or even impossible, and even BMV can fail. Many other "contextual" factors can make airway management challenging such as location, human factors, available resources, and experience of the medical team. Nevertheless, the goal remains that the patient's airway be promptly secured and oxygenation be maintained.

Responding to an identified need to reduce the incidence of airway management failure, the American Society of Anesthesiologists (ASA) issued guidelines and an algorithm for management of the difficult airway in 1993, with subsequent revisions in 2003 and 2013.[9,10,31] The guidelines stressed the importance of performing an airway evaluation for difficulty prior to inducing anesthesia and paralyzing the patient. Planned awake intubation, awakening the patient in the presence of a failed airway, and acquiring skills in alternative airway management techniques are hallmarks of the 1993 guidelines. The 2003 guidelines reemphasize the importance of the airway evaluation and incorporate the laryngeal mask airway (LMA) as a discrete step in the algorithm, should failure occur. In the 2013 guidelines VL is incorporated as a first airway management plan. The DAS have come up with simplified guidelines for management of the unanticipated difficult intubation in adults in 2015 emphasizing emergency oxygenation and ventilation techniques.[11]

Unfortunately, the ASA and DAS guidelines are less useful outside the OR, especially in circumstances in which tracheal intubation must be accomplished quickly and awakening the patient is not an option. Even in the OR setting, explicit guidelines for the rapid evaluation of an airway for occult difficulty and the prioritization of rescue maneuvers in the event of a mandated immediate intubation are not well handled by the ASA or DAS guidelines and algorithms (see Chapter 2). Furthermore, these guidelines do not take into consideration patients who are uncooperative (e.g., young children or mentally challenged patients) or different patient populations (e.g., pediatrics and near term parturients [see Chapter 51]).

Further complicating this issue are the many new, effective, and safe airway devices that have been introduced to assist with difficult and failed airway management. Flexible endoscopic and video-intubating bronchoscopes have become more portable and easier to use and have been joined by a collection of rigid optical devices and stylets (e.g., Shikani Optical Stylet™, Bonfils Stylet™, Levitan FPS Scope™, Clarus Optical Stylet™, etc.), hybrid devices employing cameras or fiberoptics, such as video-laryngoscopes (e.g., GlideScope®, McGrath® Series 5 video-laryngoscope, McGrath® MAC, King Vision®, AirTraq®, Storz CMAC®, see Chapter 11), and disposable camera tubes (Vivasight, ET View Medical).

The LMA and intubating laryngeal mask airway (ILMA or LMA Fastrach™) have assumed a distinct role in the management of both the difficult and the failed airway. In the prehospital setting the iGel (Intersurgical) and Air-Q (CookGas) have assumed a more prominent role for initial airway management, and rescue during rescucitation.[32] The Combitube™ had been used in the past as a lifesaving rescue device, though now largely replaced by the King Laryngeal Tube airway (Ambu Medical) and the EasyTube. Lighted stylet methods may permit light-guided (transillumination) intubation in situations in which the vocal cords cannot be visualized, but in the era of vision guided intubation aids, there is a decrease in use of this device. With the realization that airway rescue techniques should be done quickly, the so called "one second intubation technique" employing disposable camera tube devices (ET VIEW Vivasight®) are gaining popularity when used in combination with an EGD such as the iGel or Air-Q. Certain airways are impossible to manage by any means other than cricothyrotomy, a procedure that all airway practitioners ought to be competent to perform. Several techniques have been advocated, including the "no drop" cricothyrotomy and the "fast surgical airway" technique, a 4-step bougie-scalpel-tube technique[11,33] (see Chapter 14).

The challenge for any airway practitioner is to be able to accurately predict when a difficult airway is present, to immediately recognize when an intubation failure has occurred, and to reliably and reproducibly ensure continuous gas exchange in both of these unnerving circumstances.

STANDARD OF CARE

Is There a Prevailing Standard of Care in Managing the Difficult and Failed Airway? How Is It Defined?

The growth in knowledge and evidence related to the practice of airway management is relentless. Advances in airway management over the past two decades have significantly improved patient outcome with a reduction in the incidence of death and disability.[34] The challenge for the practitioner is to keep abreast of new information and new techniques to practice within the standard of care.

Black's Law Dictionary[35] defines the "standard of care" as:

> The *average* degree of skill, care and diligence exercised by members of the same profession, practicing in the *same or similar locality* in light of the *present state* of medical and surgical science.

This definition incorporates several important features:

- Average degree of skill
- Same or similar locality
- Present state of knowledge

Taking these into consideration, the standard of care is the conduct and skill of an average and *prudent practitioner* that can be expected by a *reasonable patient*. A bad result due to a failure to meet the standard of care is generally considered to be malpractice. There are two main sources of information as to exactly what is the expected standard of care:

- The beliefs and opinions of experts in the field.
- The published scientific evidence, standards of care, practice guidelines, protocols.

Driven by the complex nature of this clinical dilemma and the need for successful solutions that are easily learned and maintained (and cost-effective), the standard of care in airway management is exceedingly dynamic. Continuing evolution of new devices and techniques, or ways of thinking, modify the existing standard of care on an ongoing basis. It is incumbent on practitioners to keep abreast of new devices and techniques and remain facile with existing rescue techniques. They can do so by continually perusing the literature and attending educational programs related to airway management.

What Is the Role of Professional Organizations in Establishing the Standard of Care?

International, national, regional, and local professional organizations generally address issues relevant to airway management in a variety of ways. Most national societies, such as the ASA, the Difficult Airway Society (DAS-UK), the American College of Emergency Physicians (ACEP), the Canadian Anesthesiologists' Society (CAS), and others, engage in crafting practice guidelines.[10,11,16,17,36]

In the event of an untoward outcome, the *reasonable patient* expects the published guidelines to be observed by the *prudent practitioner*. Organizations that craft and publish such practice guidelines are careful to stipulate that such guidelines do not constitute the standard of care.[10,11,16] Unfortunately, guidelines are often perceived as the standard of care, particularly in a medical–legal context.

Professional organizations often provide educational initiatives to ensure that their members practice at the prevailing standard. The ASA, DAS, CAS, ACEP, and the Society for Airway Management (SAM) are good examples. SAM, DAS, and European Airway Management Society (EAMS) are organizations committed to advancing knowledge and improving the quality of airway care to all patients no matter who cares for them. These societies blend the expertise of anesthesiology, otolaryngology, head and neck surgery, critical care, and emergency medicine to the airway management debate. They also serve as sounding boards for new devices and techniques and those wishing to challenge traditional dogma to advance new frontiers. Those with a specific interest in airway management are well advised to become involved in these organizations.

How Can We Integrate the Standard of Care into Our Clinical Practice?

Despite all these initiatives, the standard of care remains elusive, particularly when applied to the management of the difficult and failed airway. It means different things to different practitioners and is situation dependent. For example,

- To the plaintiff's attorney, it must be precisely defined in minute details
- To the practitioner, it is what they do every day
- To the defendant practitioner, it is consistent with their actions

It is perhaps easier to articulate what it is not:

- It is neither much better nor much worse care than that delivered on average by one's peers.
- It is not the same as the care provided by *experts* managing difficult and failed airways every day.
- It is not what ivory tower academic experts *think* it *ought to be*.
- It is not a single study published in a reputable journal last week, or a position advocated by *experts* in an editorial in a similarly reputable journal.

We do know that the standard of care is dynamic and our patients expect to receive it at a minimum.

Perhaps the best test with respect to difficult and failed airway management is to ask a specific question: "Should the average, reasonable, and prudent practitioner…"

- Be able to recognize and manage an anticipated difficult airway?
- Be able to manage an unanticipated difficult airway?
- Be able to use a flexible bronchoscope to intubate the trachea of a patient?
- Be able to recognize and manage the failed airway?
- Be facile with one or two rescue devices or techniques in the face of a failed airway?
- Be able to work in a team, communicate clearly, and be able to perform under stressful circumstances?
- Be able to perform a surgical airway? Or at the least, transtracheal oxygenation and ventilation?

It is reasonable to expect that most practitioners charged with managing airways would answer yes to all of these questions and thereby define the standard of care.

DEVELOPMENT OF DIRECT LARYNGOSCOPIC INTUBATION

How Did the Design of Direct Laryngoscopes and the Basic Technique of Oral Laryngoscopy Evolve?[37]

Herholdt and Rafn are generally credited with first describing blind oral intubation in 1796. Subsequently, Desault described blind nasal intubation in 1814. Although Sir William Macewen described direct vision oral intubation in 1880, it is generally accepted that the first description of laryngoscopic-aided oral intubation was by Kirsten in 1895. By 1907, Chevalier Jackson, an ENT surgeon of considerable renown, introduced distal lighting to the laryngoscope, and Janeway in 1913, innovated the insertion of electric batteries into the handle of a laryngoscope to facilitate the procedure. Magill and Rowbotham engineered the straight Magill blade in the 1920s by cutting a wedge out of the side of the blade of the ENT surgeon's anterior commissure laryngoscope to facilitate intubation (Figure 1-1). Across the Atlantic, this design (with minor modifications) became known as the Miller blade in the 1940s. The Macintosh blade was also introduced in the 1940s by Sir Robert Macintosh.

Magill is credited with introducing the "retro-molar" or "paraglossal" approach, reasoning that placing the blade as far to the corner of the mouth as possible when attempting to bring the glottis into view (as opposed to being in the midline) ought to minimize the distance to the glottis and enhance the

FIGURE 1-1. The Magill laryngoscope.

degree to which it is visible. This technique has been resurrected by Henderson who developed the Henderson blade™ (Karl Storz Germany).[38]

■ How Did the Design of Endotracheal Tubes Evolve?

It was also Sir Ivan Magill (circa 1914) who recommended a left-sided bevel (Magill bevel) be created on the distal tip of an endotracheal tube (ETT) (Figure 1-2). At that time, blind nasal intubation using a non-beveled, gum-elastic tube was popular. Magill observed that, as the right nostril is usually largest and most anesthesia practitioners are right handed, nasotracheal intubation was usually first attempted through the right nostril. The natural tendency for a tube introduced through the right nostril was to deviate leftward as it transited the nasopharynx and oropharynx and to deflect off the left glottic structures into the left pyriform recess. Magill reasoned that the left-sided bevel would deflect the ETT into the glottis.[39] Left-side bevel ETTs continue to be the most commonly used tubes to this day.

Curare was first used in the 1940s and succinylcholine was introduced into anesthetic practice in 1952. These drugs led to the need for positive pressure ventilation through a tube with a tracheal seal being achieved by packing gauze (at times oil soaked) around the glottic opening. A more effective seal could be obtained by incorporating a balloon (initially rubber, thick walled, high pressure, and removable) onto the ETT. However, the possibility that the beveled orifice of the distal tip could rest against the wall of the bronchus in the event of a right mainstem intubation permitting positive pressure inspiration but not passive expiration was noted. This led to the creation of the Murphy eye opposite the bevel orifice (i.e., facing the right side).

FIGURE 1-2. The left-sided Magill bevel on the endotracheal tube.

The bulk of the ETT and balloon hindered its passage through the channel of laryngoscope blades, and this led the Eschmann Corporation to develop a tracheal introducer (invented by Sir Robert Macintosh) to facilitate a Seldinger-type intubation over the introducer in 1949.[40]

■ How Has Our Understanding of How the Difficult Airway Might be Predicted Developed Over the Years?

The use of neuromuscular blockade to facilitate orotracheal intubation followed the introduction of curare into anesthetic practice in the early 1940s and succinylcholine in the late 1940s. Up until that time, orotracheal intubation was largely performed with the patient breathing spontaneously under inhalational anesthesia. The consequence of a failed intubation was mitigated by the fact that the patient continued to breathe spontaneously. The threat of failure to intubate in the face of neuromuscular blockade and apnea required anesthesia practitioners to evaluate the airway for difficulty, leading to a landmark publication by Cass in 1956.[41] This study identified those anatomical features that might predict difficult laryngoscopic intubation. Thus, the clinical use of neuromuscular blocking agents became inseparable from the ability to perform an airway evaluation and the ability to rescue the airway in the event of failure. Many practitioners still fail to recognize a difficult airway when one exists or they overlook the evaluation altogether.[4,9]

The literature regarding the difficult airway was relatively quiet until the mid-1980s when Patil offered the proposition that a thyromental distance of less than 6 cm was associated with orotracheal intubation difficulty.[42] During the 1990s, Savva did the same by using the sternomental distance.[43] The importance of Patil's dimension rests not in the distance described, or in its lack of sensitivity, specificity, or positive predictive value with respect to airway management difficulty,

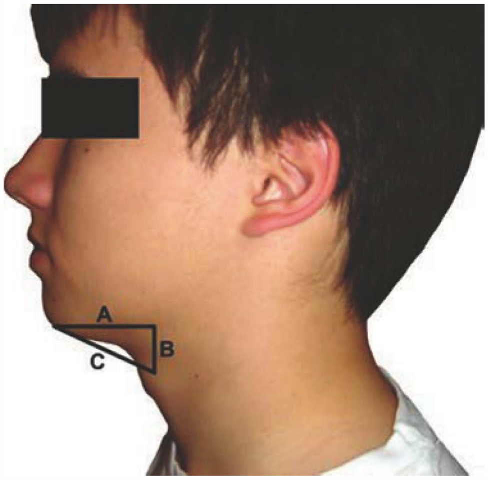

FIGURE 1-3. The Patil's triangle. **(A)** The second 3 of the evaluate 3-3-2; **(B)** the 2 of the evaluate 3-3-2; **(C)** the thyromental distance.

but in the fact that it alludes to the *geometry* of the airway. The thyromental line constitutes the hypotenuse of a right angle triangle (Figure 1-3). The axis is length of the floor of the mouth (a dimension of the mandibular space), and the abscissa locates the larynx in relation to the base of the tongue. The length of the oral axis affects the ease with which the glottis is exposed during conventional laryngoscopy: the glottis cannot be visualized beyond the horizon of visibility if it is too long; the larynx is shielded by the base of the tongue (anterior larynx) if it is too short. Likewise for the location of the larynx in relation to the base of the tongue: it is beyond the visible horizon if it is too far down the neck; it is tucked up under the base of the tongue if it is too high in the neck. Furthermore, the dimensions of the mandibular space (length, width, and depth; or volume) have important implications. The volume of the mandibular space must accommodate the tongue, as it is displaced into this space during laryngoscopy to bring the glottis into view.

Mallampati in 1983 and 1985 created a scoring system[44,45] modified by Samsoon in 1987,[46] that identified oral and pharyngeal access as an issue of importance in airway management (Figure 1-4). Although the score by itself had poor sensitivity, specificity, and positive predictive value, the notion that *access* is important became cemented.

It was during this time that Cormack and Lehane proposed their laryngeal view grade scoring system in an effort to provide some structure to the discussion of *difficult laryngoscopy* (Figure 1-5).[47] Although found to be subject to considerable interobserver variability, the scale has been embraced as a valid measure of difficulty; with Grades 3 and 4 views being equated with *difficult laryngoscopy*. By the late 1990s, other models with more reproducible scoring systems, such as Levitan's percentage of glottic opening (POGO) visible, were proposed.[48-50] However, widespread adoption of these systems over the Cormack/Lehane (C/L) system has yet to occur (Figure 1-6).

By the late 1980s, it had become apparent that airway management failure was the most important contributor to poor patient outcome in anesthesia practice, lawsuits, and financial settlements.[4] The question facing airway practitioners became: Who should you not paralyze? A variety of investigators pursued univariate and multivariate systems of analysis that attempted to answer this question, but none with reliable success[51]:

- Wilson (1988) (Wilson Risk Sum): Employed a weighted scoring system 0 to 2 incorporating body weight, head and

FIGURE 1-4. Mallampati scores.

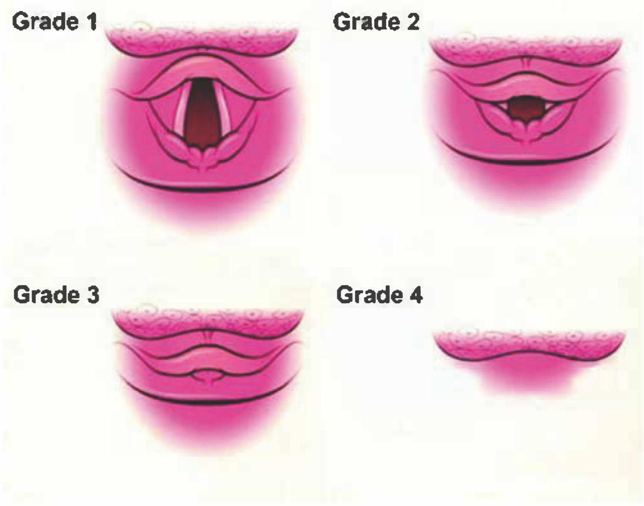

FIGURE 1-5. Cormack/Lehane laryngeal view grading score.

neck movement, jaw movement, receding mandible, and prominent (buck) teeth.[52]

- Bellhouse (1988): Used x-rays to evaluate for difficulty.[53-57]
- Rocke (1992): Evaluated 1500 parturients using a combination of Mallampati, short neck, receding mandible, and buck teeth.[58]
- Savva (1996): Identified a sternomental distance less than 12 cm as a risk for difficulty.[43]
- Tse (1995): Combined Mallampati, head extension, and thyromental distance.[59]
- El-Ganzouri (1996): In a large study of 10,507 patients looked at mouth opening, Mallampati, neck movement, mandibular protrusion, body weight, and a positive history of airway management difficulty.[60]
- Karkouti (2000): Evaluated 461 patients (38 difficult) and correlated mouth opening, chin protrusion, atlanto-occipital extension.[61]

Between 2000 and 2015 studies identified factors that reliably predicted impossible bag mask ventilation and intubation such as head and neck radiotherapy.[13,14,62-67] Kheterpal and others identified risk factors for failed video-laryngoscopic intubation such as airway pathology from previous surgery, a local mass, or radiotherapy to the head and neck.[13,14]

Hot on the heels of the "Who should you not paralyze?" question is the dilemma: "How is the airway best rescued in the event that intubation and/or ventilation is impossible, that is, a failed airway?" In the past, BMV was viewed as the most commonly performed fallback technique. This technique, difficult to teach, learn, and perform, is being supplanted by more user friendly and easily performed EGDs. This has led to a reframing of the way we think about airway management: In the event laryngoscopy and intubation fails, is it likely that gas exchange can be maintained by BMV or one of these EGD devices? Furthermore, the recognition that while aspiration is undesirable, it is not usually a deadly occurrence, serves to emphasize the primacy of gas exchange over intubation and airway protection.

There has also been a substantial change in our thinking with respect to surgical airway management. In the past, it was

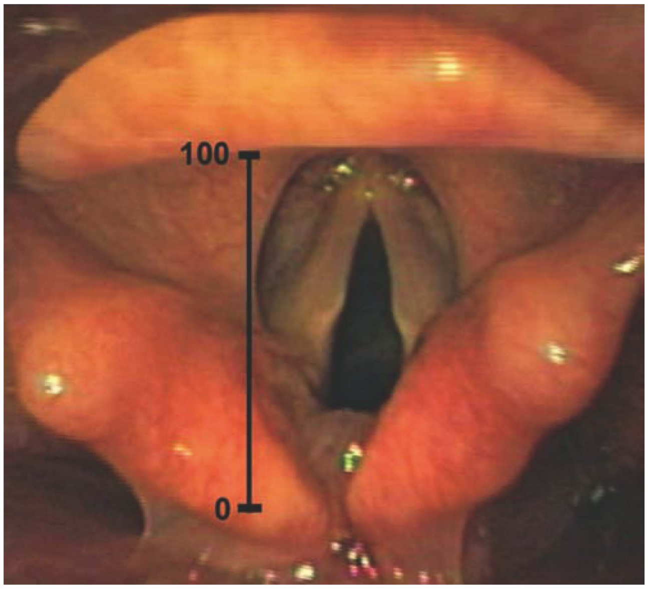

FIGURE 1-6. Levitan's percent of glottic opening (POGO): 100—if the complete glottis can be seen; and 0—if no part of the glottis can be seen.

left to the practitioner as to whether to perform a Seldinger technique or an open cricothyrotomy. In fact, it was taught that anesthesia practitioners ought to preferentially select a Seldinger technique as using a needle as opposed to a scalpel was felt to be psychologically more acceptable. However, it has become apparent that fellowship trained and certified anesthesiologists cannot reliably locate the cricothyroid membrane in elective surgical patients, particularly if they are female or obese.[5,6,68-70] The report from NAP4 identified that needle techniques were unsuccessful and open techniques were successful. So it is currently recommended that an open cricothyrotomy be performed in the CICO situation.[11]

Cricothyrotomy employed in the setting of a failed airway has become emblematic of airway management failure. It is now taught that if the airway manager considers a CICO airway even remotely possible that the cricothyroid space be identified by manual palpation or with ultrasound (Chapter 14) and the incision line marked preemptively. In other words, should a cricothyrotomy be needed, it is a deliberate "part of the plan" as opposed to "emblematic of failure." The psychology of this approach is compelling in motivating individuals to move earlier to a cricothyrotomy as soon as a CICO airway is identified. Peterson[34] and NAP4 both identified delay in performing cricothyrotomy as substantial issues leading to poor outcomes.

DEFINITIONS OF DIFFICULT AND FAILED AIRWAYS

> The Difficult Airway is something you anticipate; the Failed Airway is something you experience.
>
> *(Walls, 2002)*

As noted earlier, this chapter explores the concepts of *the difficult* and *the failed* airway. The premise is that the pre-procedure recognition and management of the difficult airway should minimize the occurrence of a failed airway. Furthermore, recognizing the failed airway promptly ought to optimize the chances that failing techniques will be abandoned and replaced by techniques reasonably anticipated to succeed.

The Difficult Airway

When one is presented with a patient that requires tracheal intubation, the first decision is whether or not this airway needs to be managed immediately. If so, immediate action is indicated.

As discussed above, unlike the failed airway the difficult airway is not so easily defined. Rather than a definition, in concept, the *difficult airway* has several dimensions[15]:

- Difficult BMV
- Difficult DL
- Difficult VL
- Difficult intubation
- Difficult placement of a EGD
- Difficult cricothyrotomy

These six dimensions can be reduced to four technical operations:

- Difficult BMV
- Difficult DL or VL and intubation
- Difficult EGD
- Difficult cricothyrotomy

The evaluation of the airway for difficulty may be leisurely or urgent. In the latter circumstance, it must be done quickly with care taken not to omit anything important.

The rapid adoption of VL has substantially affected our approach to difficult airway management in that laryngeal views are often better with VL than with DL. What is unclear is whether this "better view" is associated with higher intubation success rates. It is also noted that many devices have come to the market without robust clinical research, so now and then complications with these new devices do occur. There is some evidence that success rates are higher if one gives oneself "limited" laryngeal views (POGO 10% to 50%, superior to and superseding the older Cormack Lehane Grades 2B and 3).[71,72] It appears that the deformation of the airway by the VL device required to get that Grade 1 or 2A view maneuvers the tip of the VL to push he larynx more anteriorly creating a more acute angle for the ETT to pass.

Like well-constructed algorithms, mnemonics are efficient memory-aid strategies that lead to a complete, yet rapid, evaluation. One for each technical operation has been crafted to permit a rapid and complete evaluation, no matter the clinical circumstance.

The Failed Airway

Orotracheal intubation, BMV, or EGD ventilation may fail in isolation leading to failed BMV, failed intubation, etc. However, should all three methods fail, one is faced with a failed airway. Failure of a single method has generally been defined as:

- Failed intubation is three failed attempts at orotracheal intubation by a skilled practitioner[10,11,16,17]
- Failed mask ventilation as failure to ventilate despite best efforts employing airway adjuncts (oropharyngeal and nasopharyngeal airways) and two practitioners with or without neuromuscular blockade[63,73]
- An EGD has failed if ventilation through the device fails to detect carbon dioxide on exhalation or improve oxygen saturations. It has also been defined as an airway intervention requiring device removal and the use of an alternative technique to effect gas exchange. (Modified after Ramachandran[74])

The problem in everyday practice is not so much defining failure; it is recognizing CICO once it has occurred, and then moving quickly to alternatives.

The intent is to minimize the chance of encountering a failed airway when one might have easily predicted a difficult intubation, difficult BMV, difficult EGD ventilation, or a difficult cricothyrotomy.

The adage in anesthesia practice with respect to neuromuscular blockade of a patient who has some effective spontaneous ventilation has always been "Don't take anything away from the patient that you can't replace." While such a rigid principle is not always consistent with the realities of airway management, it is a useful one to remember!

PREDICTION OF DIFFICULT AND FAILED AIRWAY

The most effective memory aids work well as everyday practice adjuncts in *all* clinical situations. The following mnemonics fall into this category.[15] Though mnemonics may be useful as memory aids, it is good to consider their inevitable limitations.

In this regard, it is important to consider the results of a Danish group that recently reported their findings with respect to predicting the difficult airway in a large cohort of 188,064 patients, using a pragmatic approach.[75] They confirmed that the prevailing teaching related to predicting difficulty was an inexact science. Of 3391 difficult intubations 3154 (93%) were unanticipated. When difficult intubation was anticipated, 229 of 929 (25%) had an actual difficult intubation. Difficult mask ventilation was unanticipated in 808 of 857 (94%) cases. They concluded that no single predictor predicts difficult intubation. The investigators concluded that while "*prediction of difficulties remains a challenging task, there may be ample room for improvement, based on a rigorous, evidence based and systematic approach.*" This very large study serves to emphasize the need to be prepared for failure every time one manages an airway because patients unexpectedly show up with difficulties during airway management.

The landscape is further fraught by the combinations and permutations of innumerable devices and techniques used alone or in combination. For example, one could use 10 different face masks for BMV with or without an oropharyngeal airway (Guedel or Berman), with or without cricoid pressure, in the half sitting or supine position, with an inspiratory oxygen fraction of 80% or 100%. Denitrogenation can be done for