

# An Anesthesiologist's Perspective on the History of Basic Airway Management

## The “Artisanal Anesthetic” Era: 1846 to 1904

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### ABSTRACT

This second installment of the history of basic airway management covers the early—artisanal—years of anesthesia from 1846 to 1904. Anesthesia was invented and practiced as a supporting specialty in the context of great surgical and medical advances. The current-day anesthesia provider tends to equate the history of airway management with the history of intubation, but for the first 58 yr after the introduction of ether anesthesia, airway management was provided by basic airway techniques with or without the use of a face mask. The jaw thrust and chin lift were described in the artisanal years and used primarily with inhalation anesthesia in the spontaneously breathing patient and less often with negative-pressure ventilation in the apneic victim. Positive-pressure ventilation and intubation stayed at the fringes of medical practice, and airway techniques and devices were developed by trial and error. At the beginning of the 20th century, airway management and anesthetic techniques lagged behind surgical requirements. (*ANESTHESIOLOGY* 2017; 126:394-408)

“Now that anaesthetic agents are so much in vogue, it is seldom that we are obliged to tie our patients, or to roll them up in sheets and aprons, as was the custom prior to the discovery of these most useful remedies.” —Samuel S. Gross. *A System of Surgery*. 4<sup>th</sup> Edition. Philadelphia, Henry C. Lea, 1866, p 479.

ON October 16, 1846, dentist William T. G. Morton (Boston, 1819 to 1868) successfully demonstrated in front of the surgeons of Massachusetts General Hospital (Boston, Massachusetts) that inhalation of ether vapor could produce surgical anesthesia.<sup>1</sup> But the initial excitement generated by the discovery was soon followed by a long, slow, and arduous process of experimentation carried out by independent practitioners. Anesthesia at this stage lacked the cardinal features of a craft. In traditional crafts, selected individuals learn in a structured environment from trained senior craftsmen the skill and knowledge required for qualification in their occupation. But before an occupation develops into a formal craft, individual artisans practice and refine their skills independently. This was the situation of anesthesia providers in the era discussed in this article. It took 40 to 50 yr after the discovery of anesthesia before medical practitioners accepted anesthesiology as an essential part of medicine.<sup>2</sup> Before that time, administration of anesthesia was a personal exercise applied primarily by low-level or nonmedical personnel, and experience, aptitude, and luck

dictated the practice of the newly invented endeavor, with theory following practice. This artisanal approach explained anesthesiology's initial slow progress and lack of formal recognition.

A certified craftsman in a recognized trade holds a defined social position, but anesthesiology was not immediately seen or structured as a craft in its own right. John Snow (London, 1813 to 1858), a professional anesthetist in London from 1847 to 1858, whose skill and knowledge were ahead of his time, was not even recognized at his death with an obituary in either *Lancet* or the *British Medical Journal*.<sup>3</sup> Only at the end of the 19th century, when anesthesia reached craft status in some large medical centers in the Western world, did anesthesiology enter on the road to modernity.

For the first 58 yr after the introduction of ether as an anesthetic, general anesthesia used an inhalation technique applied to a spontaneously breathing patient with an unprotected airway; airway patency depended on basic airway management (BAM). Most physiologists and surgeons believed as dogma that the alveoli do not resist positive-pressure ventilation (PPV).<sup>4,5</sup> Even as late as 1904, PPV was rejected both inside and outside the operating room. In that year, the physiologist Edward S. Schäfer (London, 1850 to 1935) described yet another of many negative-pressure artificial-respiration techniques, and the thoracic surgeon Ferdinand Sauerbruch (Berlin, 1875 to 1951) developed a pressure-differential operating room to solve the pneumothorax problem in thoracic surgery on the

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spontaneously breathing patient.<sup>6,7</sup> In spite of consistent and pertinent opposition, the high standing of Schäfer and Sauerbruch in the scientific world imposed their convictions on the medical community. But also in 1904, the Roth-Dräger oxygen-chloroform apparatus developed by the Dräger Company of Lübeck, Germany, was presented at the World Exhibition in St Louis.<sup>8</sup> This heralded the end of the artisanal anesthesia era of trial and error and physician-instrument maker collaboration and the start of modern, industrial anesthesia with mass production and research and development programs.<sup>9</sup>

In the early anesthetic period, BAM techniques were unknown to the medical practitioner.<sup>5</sup> Joseph Clover (London, 1825 to 1882) remarked that anesthesia providers “were soon found to be attended with inconvenience and danger.”<sup>10</sup> So were their patients. Developing and implementing BAM were a matter of life and death. This article (the second in a series) follows the development of BAM from 1846 to 1904.

## Development of Western Medicine in the 19th Century

The practice of anesthesia was developed during a time of great change and dramatic advance in experimental science, medicine, and surgery and cannot be understood independently of these developments.

### Medicine

In the 19th century, rational analysis, clinical observation, and scientific experimentation challenged the dogmas of Galenic medicine, which asserted that illness was caused by an imbalance of the body humors: black and yellow bile, phlegm, and blood. Medical thought and practice of the early 19th century had been dominated by excitability theory, which considered health as a proper balance between internal and external stimuli. However, this theory also proved insufficient to explain empiric clinical and experimental observations.<sup>5</sup>

In the second half of the 19th century, medical thought underwent a paradigm shift from the old (traditionalist) speculative rationalism that viewed the body as a holistic system to the new (empirical) scientific rationalism that approached the body as a system of tissues and organs. The macroscopic “tissue” theory of Marie-François Bichat (Paris, 1771 to 1802) and the microscopic “cellular” theory of Rudolph Virchow (Berlin, 1821 to 1902) introduced the concept of cellular pathology. Justus von Liebig (Giessen, 1803 to 1873) showed that organic cellular processes could be analyzed by chemical methods.

Many of the new discoveries and methods had direct relevance for pulmonary medicine and anesthesia. In 1846, John Hutchinson (Newcastle, then Fiji, 1811 to 1861) measured human lung volumes using his pulmonary spirometer.<sup>11</sup> François Magendie (Paris, 1783 to 1855) and his disciple Claude Bernard (Paris, 1813 to 1878) applied experimental techniques to increase the understanding of normal and pathologic processes, as did John Dalton (Manchester, 1766

to 1844) and Paul Bert (Paris, 1833 to 1886) in the field of pulmonary physiology. In 1904, Christian Bohr (Copenhagen, 1855 to 1911) described the oxygen-hemoglobin dissociation curve. Physical diagnosis by direct examination began to be supplemented by instruments, *e.g.*, the stethoscope of René Laenec (1781 to 1826) and later by laboratory techniques and new technologies such as radiology, pioneered by Wilhelm Roentgen (Munich, Germany, 1845 to 1923) and Marie Curie (Warsaw then Paris, 1867 to 1934).

But although scientific discoveries can be traced to specific dates, changes in medical practice were slow.<sup>12</sup> The public continued to ask for traditional therapies that generated visible, familiar, and predictable effects, while the new medicine had yet to produce effective clinical treatments. Thus, depletive therapeutic techniques (bleeding, blistering, and purging) remained in use until late in the 19th century.<sup>13</sup> Only with the beginning of the 20th century did a critical mass of practitioners, patients, and the general public recognized the advantages of modern medicine.

### Surgery

Surgery in the middle of the 19th century was a rare and desperate therapeutic option. The surgical repertoire was limited and the techniques were unsophisticated, as speed was essential.<sup>14</sup> It was expected and accepted that the patient might die of hemorrhagic, septic, and/or pain-induced shock.

One of the most important surgical problems involved the prevention and control of infection. Antiseptic methods were first introduced by Ignaz Philipp Semmelweis (1818 to 1865) in Vienna in 1847 but were ignored by the medical community. Later, Joseph Lister (1827 to 1912), Professor of Surgery at Glasgow University (Scotland, United Kingdom) from 1860 to 1869, successfully applied antiseptic in surgical practice. He was able to significantly reduce postoperative infection by applying a phenol spray to the surgical wound and the surrounding area and then covering the wound with phenol-soaked dressing (“killing the germs”).<sup>15</sup> Louis Pasteur (Paris, 1822 to 1895) and Robert Koch (Berlin, 1843 to 1910) demonstrated that microorganisms were responsible for many common, often fatal, diseases and recommended aseptic techniques (“free of germs”). More rigorous aseptic strategies began to be implemented in German-speaking lands in the 1880s when Robert Koch’s laboratory-confirmed methods of steam sterilization were first applied in the surgical theater.<sup>16,17</sup> Koch’s leading proponent was Ernst von Bergmann (1836 to 1907) who trained a generation of surgeon-bacteriologists at the University Clinic in Berlin (Germany). Theodor Billroth (Vienna, 1826 to 1894), the Nobel laureate Theodor Kocher (Berne, 1841 to 1917), and Johann von Mikulicz-Radecki (Breslau, today Wrocław, Poland, 1850 to 1905) were influential in promoting the sterilization of surgical instruments and the use of face masks (FMs), special sterilized outfits, and later, surgical gloves. Anesthesia providers lagged behind surgeons in adoption of the standard operating room attire.<sup>18</sup> By the end of the 19th century, surgeons

addressed the problem of postoperative wound infection by relying on evidence-based, laboratory-tested methods that led to aseptic operating room rituals recognizable today.

Material, behavioral, and administrative changes pioneered by surgical authorities created the modern operating room with its increased surgical effectiveness and safety. The model of the surgeon as the “leader of the operative enterprise” became well accepted by the public, medical establishment, and hospital administration.<sup>19</sup> The introduction of uncomplicated anesthesia techniques allowed the surgeon to delegate this function to other providers. But inhalation anesthesia did not immediately impact surgery. Most surgical procedures addressed superficial and peripheral pathology until well into the 1890s.<sup>20</sup> In 1882, Carl Langenbuch, surgeon at the Lazarus Hospital in Berlin, Germany, performed the first cholecystectomy.<sup>21</sup> Additional invasive surgical procedures followed, requiring prolonged anesthesia. At the end of the 19th century, bacteriology and anesthesia had propelled surgery to the forefront of medical sciences. The surgeon became a highly respected professional.

### General Anesthesia

Ether and chloroform were the primary agents used for inhalation anesthesia, and physicians, academics, and the public argued over which should be used: ether was safe but irritant; chloroform was unsafe but pleasant. Estimated mortality at the end of the 19th century with chloroform was one in 2,000 to 2,500 and with ether one in 25,000.<sup>22</sup> In comparison, nitrous oxide inhaled in a 100% concentration was pleasant but generated a light and short anesthetic effect.

Open inhalation anesthesia was the simplest and most popular mode of administration of an anesthetic agent. In the United States, the technique of freely “pushing” ether on a conical sponge was used almost exclusively.<sup>23</sup> Pouring chloroform “powerfully and speedily” on a folded handkerchief held over the face of the patient was described in 1847 by Sir Young Simpson (Edinburgh, 1811 to 1870) and became the preferred method in Scotland. James Syme (Edinburgh, 1799 to 1870) and Joseph Lister gave chloroform on an ordinary towel. In 1860, Simpson changed his technique to “drop-by-drop” administration. In 1862, Thomas Skinner (1825 to 1906), a Liverpool obstetrician, developed the first wire-frame mask, covered by a simple layer of lint. Many wire-frame masks (Murray, 1868; Julliard, 1877; Esmarch, 1880; Schimmelbusch and Kocher, 1890) and simple open inhalers (Allis, 1874; Silk, 1893) followed. The open technique was a crude, wasteful, and inexact method of administration, but it was perceived as simple and safe and consequently delegated with confidence to less experienced administrators.

Inhalers were a further development in anesthetic practice. Primitive models of draw-over vaporizers powered by the patient’s breathing were built with the unfulfilled goal of regulating air and agent intake. Multiple ether inhalers (Snow, 1847; Clover, 1877; Dubois, 1885; Wanscher, 1890; Hewitt, 1901; Probyn-Williams, 1903) and chloroform inhalers (Murphy, 1850; Junker, first blow-over apparatus, 1867;

Trendelenburg, 1869; Hewitt’s modification of Junkers, 1890; Vernon-Harcourt, 1903; Waller, 1903) were described all over the world. Most were cumbersome and generated hypoxic mixtures, rebreathing, and high respiratory resistance. The inhalers were perceived as complex and dangerous devices in the hands of less experienced administrators.

Administration of nitrous oxide was technology dependent; in 1868, it was available as a compressed gas in metal cylinders (Coxeter, London). It was a weak anesthetic, and it induced asphyxia when administered in 100% concentration. During recovery, the normal color of the face returned from the “ashen hue to a natural crimson.”<sup>24</sup> In 1876, Joseph Clover’s nitrous oxide/air/ether apparatus allowed methods of sequential induction; Frederic W. Hewitt (London, 1857 to 1916) followed in 1893 with his own apparatus. Nitrous oxide anesthesia use largely depended on the FM seal.

John Snow had developed the FM covering both the nose and the mouth in 1847 by adapting the soft nose-piece and mouthpiece used by Francis Sibson (London, 1814 to 1876) to administer ether for the treatment of facial neuralgia.<sup>1</sup> It had a symmetrical design, soft material on the edge to fit the face contour, and inspiratory and expiratory valves incorporated in a body made of pliable sheet lead. Replacing ineffective mouthpieces and nares blockers, the FM became the iconic tool of the anesthetist.<sup>25</sup> Clover’s valveless FM, used with nitrous oxide, was made of sheet lead covered with leather easily molded to the face and edged with india-rubber tubing filled with air or water to create an airtight seal (fig. 1) In the United States, the first FM was patented by Lewis Roper (Philadelphia) in October 1848. It was attached to his inhaler and “shaped to fit closely over the mouth and nose.”<sup>26</sup>

Use of an inhaler required an expert to hold the mask, generate a seal, provide airway patency, manipulate the stopcock or the expiratory valve, supervise the functionality of the device, and monitor the patient and the surgical procedure. The amount of agent and air administered was inferred clinically by observing the respiratory sounds and rate, pupils, color, and pulse of the patient. Snow described five clinically relevant degrees of etherization.<sup>27</sup>

House officers, general practitioners, medical students, nurses, and nonmedical personnel under the surgeon’s supervision administered most of the anesthetics. Few anesthetist-physicians practiced in London. For most practitioners, knowledge was empirical or anecdotal, and experience with a certain technique or agent dictated the practice.<sup>28</sup> Different agents and methods of administration were adopted in different countries. The practice of anesthesia was still fully artisanal. Duncum and Thomas have reviewed inhalation techniques and devices.<sup>29,30</sup>

## BAM in Resuscitation: The Apneic Victim

### Negative-Pressure Ventilation

In the first half of the 19th century, PPV artificial respiration (bellows and mouth to mouth) was abandoned out of fear



**Fig. 1.** Center: Clover portable regulatory inhaler with face mask (cca. 1876, England); left to right counterclockwise: Esmarch chloroform mask (cca. 1877, Germany), Schimmelbusch mask (cca. 1889, Germany), leather mask from a Clover inhaler, unidentified metal mask (cca. 1930). Picture taken by the author at the Wood Library-Museum of Anesthesiology, Schaumburg, Illinois, with their kind support.

of pulmonary damage.<sup>5</sup> Negative pressure ventilation (NPV) dominated the field. As of 1958, around one hundred manual NPV techniques had been described.<sup>31</sup> These techniques relied on the manipulation of the victim's arms and body to generate alteration in the capacity of the thorax, mimicking normal respiration. Evidence of NPV effectiveness was limited to the experience and testimony of the inventor and/or an evaluation on cadavers.

Providers recognized the need to provide airway patency in resuscitation efforts. In 1857, Marshall Hall (1790 to 1857), a physiologist from Nottinghamshire, criticized the Royal Humane Society's supine position for resuscitation ("the tongue falls backward and closes the glottis") and recommended turning the drowned victim from prone ("the tongue falling forward") to lateral position for inspiration and applying back pressure for expiration.<sup>32</sup> No rescuer was dedicated to active airway management. Hall argued to abandon the old term "asphyxia" ("a" [without] and "sphyxis" [heartbeat] in Greek) meaning "want of pulse." It was misleading in resuscitation, as it was thought to require ineffective and time-consuming warming of the victim to the exclusion of the true remedy: artificial respiration. He recommended the term "apnoea" ("a" [without] and "pnein [to breathe] in Greek) or "want of respiration," which was to be associated with artificial respiration: "the one idea which ought to guide us in practice."<sup>33</sup>

In 1858, Henry Robert Silvester (1828 to 1908), a young practitioner in South London, introduced a supine chest-pressure, arm-lift technique with the rescuer at the victim's

head. Airway patency was provided passively, with the head hyperextended by a roll of clothing under the shoulders, hanging over the edge of the table, or turned to the side, or actively, by an operator pulling the tongue forward. Silvester also described what seems to have been a chin lift: "If the lower jaw be gently raised the teeth may be made to hold the tongue in the required position."<sup>34</sup> In 1861, the Royal Humane Society made Silvester the honorary medical assistant to the society. The U.S. Bureau of Mines recommended the technique until the 1950s. In 1895, Hare confirmed the superiority of the Silvester method over Hall's by an experiment in which the respiratory tract of the subject was connected with a gas meter by means of a two-way tube (thus bypassing the upper airway obstruction and making BAM obsolete). "Curare was used to prevent voluntary breathing," he reported, but no further technical details of the experiment were given.<sup>35</sup>

In 1877, the New York surgeon Benjamin Howard (Chesham, England, then New York, 1836 to 1900) proposed a modification of the Silvester method with the rescuer facing the supine victim and pressure applied on the lower costal area.<sup>36</sup> A roll of clothing placed under the patient's spine made the subcostal margin prominent and generated "the utmost extension backward of the head and neck," precluding the closure of the glottis by the epiglottis, tongue, and soft palate.<sup>37</sup> A second (optional) rescuer would keep the "tongue immovably fixed forward." Howard questioned the free airway credited to the prone position.<sup>38</sup>

In 1904, Schäfer introduced a chest-pressure technique with the patient in prone position and demonstrated its effectiveness on volunteers who hyperventilated to become apneic (albeit not reproducing the unconscious victim's muscular flaccidity and airway obstruction). This technique dominated resuscitation until 1946.<sup>39</sup> Schäfer "strongly" contraindicated the supine position because of airway obstruction but ignored the existing airway maneuvers. He believed that the prone position with the head turned to the side would circumvent the "obstruction by tongue."<sup>40</sup> Systematic scientific evaluation of airway obstruction and artificial respiration maneuvers was not performed until the mid-20th century, when it was demonstrated that neither prone nor lateral position ensures an open pharynx, but only full extension of the head or forward displacement of the mandible.<sup>41</sup>

An exception to the manual techniques was the Parisian neurophysiologist Jean Vincent Laborde's (1830 to 1903) forceps technique, described in 1894. Laborde advocated using the forceps to rhythmically pull the tongue in order to stimulate the lingual and pharyngeal branches of the trigeminal nerve and subsequently the respiratory center.<sup>42</sup> The "rhythmical traction of the tongue has been employed by anesthetists as an incentive to produce inspiration in cases of deep narcosis for some considerable time," he reported.<sup>43</sup> His technique possibly combined stimulation with an open airway, thus supporting vestiges of spontaneous ventilation.

NPV techniques were used all over the world. The selection of a specific technique reflected local tradition, national affinities, misinterpreted science, and/or bureaucratic decision-making. In 1908, The Royal Life-Saving Society had adopted the Schäfer method, the Royal Humane Society retained Silvester's, while the National Lifeboat Institution continued to recommend Marshall Hall's and Silvester's.<sup>39,40</sup>

The failure to emphasize airway obstruction and the lack of application of active airway maneuvers (see next section) was pathognomonic of NPV techniques; most illustrations depicted postural airway management with one rescuer performing artificial respiration. In the search for a simple technique, a second rescuer dedicated to active airway management (usually pulling the tongue forward) may have been perceived as a disadvantage. Postural airway management failed in practice, as the extreme flaccidity of the victim allowed the flexing of the head with the lifting of the arms and movement of the body, thus generating an iatrogenic airway obstruction.<sup>31</sup> Frustration with manual techniques is evident in Keith's review, in which he pointed out that with manual techniques, the operator has "difficulty in knowing whether or not air is entering or leaving the lungs freely; with the direct inflation [mouth-to-mouth] one knows the effect immediately."<sup>43</sup>

### Positive-Pressure Ventilation

Surgeons resuscitating curarized animals in the laboratory recognized the feasibility of PPV but were unable to provide a practical application in humans.<sup>44,45</sup> There were some remarkable exceptions. George Fell (Buffalo, New York, 1849 to 1918), trained as an engineer and physician, revived the bellows for artificial forced respiration. He was disillusioned with the ineffectiveness of NPV techniques and used PPV on narcotic- and anesthetic-overdosed patients at a time when the public could freely purchase opiates. He adapted an animal-laboratory "foot bellows—unidirectional valve—tracheotomy" apparatus to apneic humans. Fell started to apply PPV in 1886, and by 1896, there were "some one hundred human lives" saved.<sup>46</sup> Realizing that tracheal intubation or tracheotomy would deter many users, he recommended an air cup that covered both mouth and nostrils for the acute phase, followed by tracheotomy for prolonged ventilation. Fell designed his own valveless FM with a hard rubber dome and edges coated with dental wax, which by heating adapted "to the outline of [the] face."<sup>47</sup> There was no previous experience with FM PPV, and the practitioners associated with Fell struggled with mask seal, stomach and bowel inflation, and aspiration. To reduce stomach inflation, they pressed the larynx "back against the oesophagus," a technique known since the 18th century.<sup>5,48</sup> FM ventilation of the unprotected airway was also hindered by traditional resuscitation techniques such as stimulants (strong coffee injected into the stomach) and emetics.<sup>49,50</sup> In two reported cases, airway obstruction required ligatures with suture silk to fix the tongue forward. In a prolonged case (11 h), the

FM ventilation deteriorated, as the neck extension and the ligatured tongue failed to provide airway patency. Fell considered that delaying tracheotomy was a mistake. There is no mention of jaw thrust, postural airway management, or any specific FM grip to optimize the seal. Fell's technique added not only the use of an apparatus to deliver PPV but also airway management responsibilities that went against the accepted narrative of simple NPV techniques applied by unskilled personnel.

Fell recommended the FM in short cases and intubation and tracheotomy in longer respiratory arrest cases. In 1894 (against the initial ridicule of the current assistance), he saved a medical student intoxicated with strychnine, morphine, and atropine after 80 (discontinuous) h of forced respiration. Remarkably, he supported the patient with oxygen, administered nutrient enemas, catheterized the bladder, and gave food and medicine by mouth when possible.<sup>51</sup> The inability of a conservative medical community to grasp Fell's concept of acute care with PPV "without danger to the delicate lung tissue" was measured in lost lives inside and outside the operating room. The subsequent application of the Fell-O'Dwyer apparatus for elective surgery with an intralaryngeal tube revolutionized neurothoracic (1894) and intrathoracic (1899) surgery.

Mouth-to-mouth ventilation was used in neonatal resuscitation.<sup>52</sup> In France, neonatal resuscitation was supplemented with metallic tracheal tubes for PPV by De Paul (1845) and Ribemont-Dessaignes (1877). The familiarity of surgeons with tracheotomy (as opposed to intubation) established this invasive procedure as the definitive airway management option in resuscitation.<sup>53</sup> Endotracheal intubation was kept at the fringes of medical practice and reinvented all over the Western world: J. Eugene Bouchut (Paris, 1818 to 1891), Joseph O'Dwyer (New York, 1841 to 1898), William Macewen (Glasgow, 1848 to 1924), Franz Kuhn (Kassel, 1866 to 1929), Alfred Kirstein (Berlin, 1863 to 1922), and Karel Maydel (Prague, 1853 to 1903).

### BAM in Anesthesia: The Spontaneously Breathing Patient

Inhalation anesthesia required elective and emergent airway management. Initially a short and light anesthetic was sufficient for limited surgical procedures. With a light anesthetic, pharyngeal reflexes and muscular tonus were maintained, providing a patent airway, and the patient's own movement, vocalization, cough, and swallowing were expected to effectively clear the airway of secretions and blood. In the last quarter of the 19th century, a prolonged and deeper anesthetic producing abdominal muscle relaxation was required. Airway patency became a challenge.<sup>54</sup> Airway obstruction—snoring, stertor, and puffing of the lips—was the preferred marker of anesthetic depth. The anesthetist was able to work entirely by the sound of the respiration. Stertor was the sign to stop the administration of the anesthetic in short operations and to lighten the anesthetic or

apply an airway maneuver in longer ones. The hands of the administrator were busy with holding the mask, operating the inhaler, dripping the agent, taking the pulse, removing secretions, applying airway maneuvers, and, with light anesthesia, monitoring swallowing.<sup>55</sup> Cyanosis was not considered an alarming phenomenon. There was no differentiation between asphyxia caused by breathing a hypoxic mixture and that caused by airway obstruction.<sup>56</sup> Air-limitation-induced hypoxia was accepted, as it intensified and prolonged the anesthetic. Cyanosis became a “tolerated concomitant of general anesthesia” for many years.<sup>57</sup> In this context, sub-optimal airway management was not sanctioned and was frequently led to complications.

### *Airway Maneuvers in the Preanesthetic Era*

In the mid-19th century, the anesthesia provider had few models of BAM for unconscious patients. In resuscitation, airway management was provided by postural techniques or by the forceful opening of the mouth and pulling forward of the tongue.<sup>5</sup> In 1860, Robert Bowles (Folkestone, England) discussed the pathology and treatment of the “loud and deep sound” in apoplexy (stroke). After experiments on cadavers, he considered as possible causes the paralyzed soft palate and airway obstruction by the tongue or the pharyngeal contents (vomit, saliva). Bowles cautioned about the dangers to the supine unconscious patient from the “falling back of the tongue causing sudden and complete apnoea.”<sup>58</sup> He advised repositioning the patient from supine to lateral, hooking the tongue with a forceps or the fingers, or pressing it with a spoon, and evacuating the contents of the mouth. Bowles correctly described the “mandible–tongue” relationship in the supine unconscious patient: an open mouth obstructed the pharynx (“dropping jaw and tongue”), while the closed mouth with the mandibular symphysis at its greatest distance from the cervical spine would lift the tongue from the pharynx. In his 1880 follow-up, he deplored the lack of advancement in the field of airway obstruction. Bowles also added Lister’s laryngeal stertor to the list of potential causes of airway obstruction.<sup>59</sup>

No airway management was needed for the superficial anesthesia generated by soporific sponges, first used in the Middle Ages and rediscovered in 1847, and by mesmerism—an offshoot of the methods of the 1840s’ traveling magnetists who induced trance in volunteers.<sup>60–62</sup> In the 1840s, ether and nitrous oxide frolics were very popular in Great Britain and especially in the United States. The Long–Wells–Morton–Colton lineage was exposed to frolics before taking their places in the pantheon of anesthesia. In these frolics, the sitting participant was voluntarily breathing through the mouthpiece connected to the agent source until unconsciousness intervened and the mouthpiece dropped, self-limiting the experiment. This technique, generating light and short unconsciousness and analgesia without the need for airway management, represented the initial model for inhalation anesthesia.

### *Airway Maneuvers in Anesthesia*

Early attention to airway management in anesthesia focused on the tongue. The state of airway management more than a decade after the discovery of anesthesia was well described by the following case, in which the operating physician was responsible for inhalation anesthesia and airway management: “One of the first persons that I ever saw on the operating-table nearly died from this cause [tongue obstruction] during the operation under the influence of chloroform. Mr. Syme who was operating fortunately guessed what was the cause of the sudden asphyxia and drew the tongue forward with a pair of forceps and the patient presently recovered.”<sup>58</sup>

Snow considered stertorous breathing the sign of deep anesthesia, prompting withdrawal of the anesthetic. His literature review on chloroform-related death covered artificial respiration provided by NPV and PPV (mouth to mouth, mouth to nose, tracheotomy, and tracheal intubation) as well as by galvanism applied to the diaphragm.<sup>63</sup> He believed that the tongue required manipulation (pulling forward) only when respiration ceased. While traditionally this is considered an error, Snow was probably the victim of his own clinical skill at titrating anesthesia to minimal stertor while maintaining muscular tonus.

Simpson, Syme, and Lister (Edinburgh School, Scotland, United Kingdom) recommended pulling the tongue forward during chloroform anesthesia as a response to “signs of danger.”<sup>64</sup> In 1863 in France, practitioners were recommended to pull out the tongue immediately after the patient was anesthetized and keep it out as a “rather preventive than therapeutic” measure [“*plutôt préventive que curative*”].<sup>65</sup> In 1892, an American surgeon visiting Paris recorded this preventive technique performed as soon as full narcosis was produced. The tongue was pulled out and the tongue forceps dropped to the side, securing the airway for the entire operation.<sup>66</sup>

The use of the tongue forceps was not without controversy, as became clear in the first airway management debate between Lister and Clover, in 1871. Lister supported the pouring of chloroform on a handkerchief by a junior officer with no special training; Clover advocated slow and controlled induction administered by an expert with an inhaler.<sup>67</sup> Lister was a supporter of drawing forward the tongue with a vascular forceps when “respiration becomes obstructed before the circulation fails.”<sup>68</sup> Clover described an airway maneuver that seems to be a chin lift with head extension: “Raising the chin and pulling it as far as possible away from the sternum” to “give effect to the muscles between the chin and hyoid bone.” His original description was in 1868.<sup>10</sup> Lister used the tongue forceps reactively in critical situations; Clover applied the airway maneuver prophylactically: “whenever any laryngeal obstruction has been threatened, I have prevented it by raising the chin and never have been obliged to draw on the tongue.” Clover stressed the relationship between a controlled inhalation technique and an atraumatic airway maneuver.<sup>69</sup>

In 1874, the Norwegian surgeon Jacob M. Heiberg (Christiana/Oslo, 1843–1888) described the two-hand jaw thrust drawing forward under the jaw in a British and a German journals. The practitioner is standing behind the patient, and as long as the lower mandible is kept sublaxated the lower row of teeth comes in front of the upper row and the maneuver had the effect as if the tongue had been drawn forward. He assumed the maneuver lifted the tongue and the epiglottis. The need for a rescue airway maneuver was a “daily occurrence in every surgical infirmary.”<sup>70,71</sup>

C. Langebuch, a German surgeon, disputed Heiberg’s priority, claiming that Heiberg learned the two-hand jaw thrust from the German surgeon Friedrich von Esmarch (Berlin, 1823 to 1908) in the winter of 1870 to 1871 while visiting as a “foreign physician” [ausländischer Arzt] at the Military Hospital in Berlin (Germany) where Esmarch practiced during the Franco-Prussian war.<sup>72,73</sup> Heiberg replied that in his year-long medical travels in Germany, he was not exposed to the jaw thrust, but regardless of the inventor, the most important aspect of the Heiberg–Langebuch conversation was the spread of knowledge of this important technique. Esmarch tactfully responded that he had been using the technique since 1866, when J. S. Little, an unidentified British surgeon, visited Kiel on his way to Shanghai and taught him the maneuver.<sup>74</sup>

In the same year, Clover reiterated his chin lift and pointed not only to the epiglottis as obstructing the trachea but also to the danger of spasm of the glottis when chloroform was poured upon a hollow sponge. The latter was considered a self-limited phenomenon leading to imperfectly oxygenated blood, with insensibility produced “partly from deprivation of oxygen, and partly from the action of ether.”<sup>75</sup>

In 1877, Esmarch described a jaw thrust accomplished by pulling the mandible upward and forward with the head slightly extended (“Esmarch handgriff” later to become “Esmarch-Heiberg grip”) (fig. 2) He asserted that this maneuver mobilized the root of the tongue, hyoid, and epiglottis, freeing the entrance to the larynx.<sup>76</sup>

In 1880, in his textbook *Anaesthetica*, the Swiss surgeon Otto Kappeler (1841 to 1909) offered a sophisticated understanding of airway obstruction (tongue, epiglottis, and soft palate) and recommended both passive (Howard’s head hyperextension) and active airway maneuvers: the Esmarch-Heiberg (with the provider behind the victim) and his own jaw-thrust technique (with the provider in front of the victim). He stated that in extreme cases of convulsive jaw contractions, accessory instruments (mouth openers, gags, and tongue forceps) were indicated. Kappeler mentioned not only Hall and Silvester’s NPV but also mouth-to-mouth technique, albeit without airway maneuvers.<sup>77</sup>

In 1888, Benjamin Howard of artificial respiration fame (see Negative-Pressure Ventilation) published a description of his new way of lifting the epiglottis. After experimenting on nonrigid cadavers, he demonstrated that “contrary to the general belief, traction upon the tongue, however the

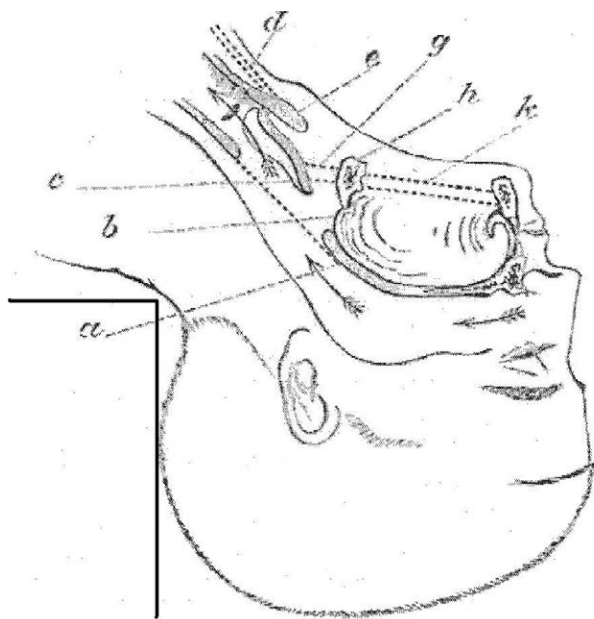


**Fig. 2.** Esmarch-Heiberg grip (1877): jaw thrust with the mandibular teeth protruded in front of the maxillary teeth. Reprinted with permission from Esmarch F: *Handbuch der kriegschirurgischen Technik*. Hanover, C Rumpler, 1877, pp 115–7.<sup>76</sup>

force employed, does not and cannot raise the insensitive epiglottis” because the attachment of the posterior fibers of the genio-hyo-glossi muscles “is not so much to the body of the hyoid bone as to the greater cornua,” thus reducing the traction impact of the tongue on the epiglottis.<sup>78</sup> He described head extension “at the occipitovertebral articulations, and also of the first and second cervical vertebrae” as the means to raise the epiglottis, tongue, and uvula off the posterior pharynx. Howard recommended the positioning of the head in extension before induction to preemptively address airway obstruction and to provide an optimal position for an emergent tracheotomy. Then “with one hand under the chin and the other on the vertex steadily but firmly carry the head backwards and downward” until the “skin from the symphysis to the sternum is quite tense” and “make the line of skin from the chin to the sternum as straight as it can be made.” Extension “should be more than rather less,” as “a slight insufficiency might bring the operator failure and the patient death.” Many practitioners were concerned that maintaining the head extended to the utmost would inflict injury. Howard replied that “the firm wedging together of the cervical spinous processes” assured the safety of the maneuver. This maneuver transformed the pharynx from a “tortuous, angular, flaccid canal to a straight curved tube.” There were no comments on the jaw thrust. On cadavers, Howard measured the maximum head extension at the occipitoatlantoaxial joint, adding objectivity to the clinical markers he described. He explained the success of this maneuver by the three-linked chain: mandible to hyoid to epiglottis, connected by the suprahyoid muscles and the hyoepiglottic ligament (fig. 3). He recommended the maneuver “from the commencement and throughout the inhalation,” so that stertor would be an unusual occurrence.<sup>79,80</sup>

J. F. W. Silk, anesthetist to the Great Northern Central Hospital, London (United Kingdom), gave a clinical rebuttal to Howard's view of the only way of raising the epiglottis and recommended adapting airway maneuvers to the clinical context. Silk mentions that the extension of the head is not "by any means a new suggestion." We do not know if he referred to Clover's technique or to maneuvers used independently by practitioners.<sup>81</sup>

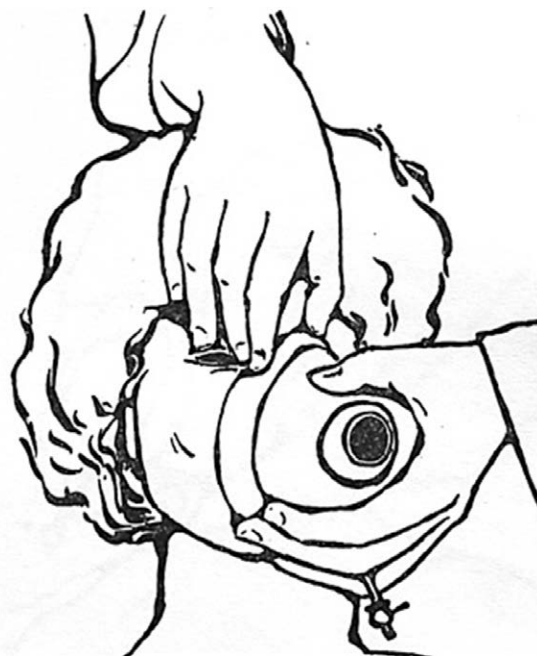
Edward Martin and H. A. Hare from the University of Pennsylvania (Philadelphia, Pennsylvania) repeated Howard's cadaver experiment, agreed with Silk that the tongue is the major culprit and recommended grabbing the tongue forcefully from the dorsum (not from the tip). They also pointed out correctly that in Howard's technique of forceful neck extension, the mouth is closed and the nasal route could be compromised by common pathology. Pulling the tongue forward would open the oral route. For routine anesthesia cases, they recommended using a moderate head extension. They stated that if this failed, a chin lift (the hand on the chin extending it so the weight of the head falls upon the occiput) or a two-hand jaw thrust with simultaneous head extension (today's triple-airway maneuver) should be used. With persistent obstruction, they recommended drawing the tongue forward.<sup>82</sup> In 1895, Hare described the sniffing position: "the head is extended and simultaneously projected forward," a technique that lifted the tongue, epiglottis, and soft palate, allowing oral and nasal respiration.<sup>35</sup>



**Fig. 3.** Howard's description (1888) of utmost extension of the head and neck at the edge of the bed with mouth closed (bed added by the author). This maneuver relieved the obstruction generated by the soft palate (a), tongue (b), and epiglottis (c) while relying on a patent nasal ventilation route (arrows). Howard B: A new and only way of raising the epiglottis. *BMJ* 1888; 1455:1106, with kind permission for publication from the *British Medical Journal*.<sup>79</sup>

In 1893, C. L. Bard, President of the Southern California Medical Society, (Los Angeles, California) recommended that once "insensibility is reached the head is extended to its fullest limit and held so by the hands of [the] anesthetizer." The distance between chin and sternum in the flexion and extension of the head measured "from actual contact to seven or eight inches."<sup>83</sup> The German surgeon Oskar Witzel (1856 to 1925) and Prof. Trélat of La Charité Hospital in Paris used postural head hyperextension at the edge of the table, with the head slightly inclined forward, just like "a runner that is breathing hard." This position placed the pharynx at a lower level than the larynx, thus protecting the airway from blood and secretions.<sup>84,85</sup>

In 1901, R. J. Probyn-Williams (1866 to 1952), anesthetist at the London Hospital (London, United Kingdom), addressed the problem of maintaining an open airway while using an FM. He described a mask grip that was used to provide a seal and a patent airway. The thumb was resting just above the connector with all the rest of the fingers below it. One, two, or even three fingers were placed under the chin to lift it away from the sternum: the head extension was built into this first-described one-hand FM grip (fig. 4). The author recommended that the fingers should remain on the chin to maintain a patent airway even when the FM is temporarily removed for air. The other hand placed behind the mandibular angle on the opposite side was "moving the jaw forward," augmenting the chin lift.<sup>86</sup> The misconception that a jaw thrust can be achieved with one hand is



**Fig. 4.** Probyn-Williams one-hand face mask grip (1901) with fingers 4 and 5 on the chin generating a chin lift/head extension. There is no strap holder on the dome. Reprinted with permission from Probyn-Williams RJ: A practical guide to the administration of anaesthetics. London, New York, and Bombay, Longmans, Green and Co., 1901, pp 73.<sup>86</sup>



perpetuated today in the “E-C” generic one-hand technique with fingers 1 and 2 around the dome of the mask (the “C”) and finger 3 and 4 along the mandible with the little finger at the mandibular angle (the “E”).

A wire-frame mask did not need a perfect seal. The mask was held half an inch from the face to allow air to mix with the anesthetic vapor. The whole dome was exposed to the dripping of the agent, with fingers one and two controlling the mask and the rest of the fingers oriented around the chin or mandible, stabilizing the mask. This allowed the provider to follow the moving face of an agitated patient, a feat difficult to achieve with a handkerchief not stabilized by a grip. The little finger in the grip was used to feel the facial arterial pulse or the anterior neck structures for deglutition.

A common position used in the supine and deeply narcotized patient was with the head turned to the side. It was assumed that the tongue fell not posteriorly, but into the cheek. This position also allowed immediate access to the cheek for clearing vomit or abundant secretions with a towel or surgical sponges.<sup>87</sup> When the head was turned to the right, the left arm of the anesthetist was resting on the patient’s left face with the palmar margin and the left little finger supporting the lower jaw.<sup>88</sup>

Surgeons, however, were unconvinced that noninvasive airway maneuvers had the same impact as invasive ones. It was their belief that, instead of complicated inhalers, the anesthetist needed a “powerful big handled gag and a first rate tongue forceps” that should be used immediately, “not fumbling about the angles of the jaw.”<sup>89</sup>

At the turn of the 20th century, textbooks presented a large variety of airway management techniques. The Esmarch-Heiberg and Kappeler, head extension, and postural techniques were used to maintain a patent airway throughout anesthetic administration.<sup>90</sup> Preference was given in emergency to pulling the tongue forward with forceps. Hewitt’s approach for continuous and immediate airway management is valid today: “obstructed respiration should be immediately corrected, for the longer it persists, greater will be the difficulty in overcoming it.”<sup>91</sup>

### Resuscitation in Anesthesia

The need for resuscitation during inhalation anesthesia occurred frequently, as the techniques were ill-defined and many practitioners inexperienced or untrained.<sup>92</sup> In the early anesthetic period, stimulants were still popular: slapping, lip friction, cold water, ammonia, exercise, subcutaneous injection of normal saline solution, and hypodermic injection of strychnine, digitalin, ether, or whiskey were all used.<sup>93</sup> Spastic asphyxia, manifested by violent spasmodic movements of the muscles and glottic closure, was not well understood but required immediate forceful opening of the mouth with separation of the jaw followed by pulling the tongue forward. Paralytic asphyxia occurred during deep anesthesia with complete relaxation of the muscles and was characterized by heavy and stertorous respiration with intercostal

retractions; it required stopping the anesthetic, applying an airway maneuver, and then pulling the tongue forward.<sup>94</sup> In most cases, airway management was reactive, being applied emergently. Tracheotomy was a technique of last resort and the one preferred by surgeons.<sup>95</sup>

When breathing stopped, artificial respiration with NPV traditionally followed. PPV was foreign to most providers. However, just as in past centuries, midwives who witnessed neonatal apnea often applied mouth-to-mouth ventilation; there are examples of PPV being applied for anesthetic apnea.<sup>5</sup> In 1848, Sibson invented a unique chloroform inhaler that could be used emergently to perform mouth-to-mask PPV. While he recommended the historical technique of pressing the larynx against the esophagus to minimize stomach inflation and to imbed the mask firmly on the face for a good seal, he did not mention any airway maneuver.<sup>96</sup> D. Plouviez (Lille, France), a military surgeon, in 1849 recommended insufflation with a bellows in chloroform apnea, as he was successfully applying the technique in overdosed animals in the laboratory.<sup>97</sup>

In 1887, Paul Thiéry at the Hôpital de la Pitié, Paris, France, performed prolonged PPV in two patients, using a laboratory mechanical device for curarized dogs. Artificial respiration in these cases followed the logical sequence of pulling the tongue forward, NPV, PPV (mouth to mouth, mouth-to-tracheotomy cannula, manual bellows to cannula), and finally the laboratory mechanical bellows-to-cannula. Tracheotomy followed prolonged and arduous mouth-to-mouth ventilation with stomach inflation. Both patients recovered spontaneous ventilation and consciousness but later died. After her initial recovery, the second patient was offered champagne and *café glacés* as postresuscitation stimulants, but she settled for beer. This case was probably the first anesthetic overdose (47 min of chloroform for an ovariectomy) to be mechanically ventilated (bellows with a crank) with a protected airway (tracheotomy).<sup>98–100</sup> In 1896, Fell described the use of forced respiration for respiratory arrest in deep narcosis with ether and chloroform. The nitrous oxide case mentioned in the same article was a nurse who repeatedly premedicated herself with hypodermic morphine for tooth and headache before the anesthetic.<sup>51</sup>

In 1891, Laborde advocated PPV for artificial respiration in chloroform-related apnea and described a face-mask-bellows system. Since Laborde’s compatriot Leroy d’Étiolles’s experiment in 1827, the teaching was that PPV destroyed human alveoli, and Laborde did not comment on the safety of the technique. He addressed both components of the BAM he used: an airtight seal [*“quasi hermétique”*] and a patent airway. For the latter, he described (no illustration) an “oropharyngeal airway” as a tube with one end functioning as a tongue depressor and the other connected to the mask. He did not mention airway maneuvers. Laborde’s bellows (like the one developed by Leroy d’Étiolles) was calibrated for safety.<sup>101</sup> Because “forced respiration” had already been used in Europe, Fell criticized Laborde for presenting PPV as a “new” method but failed

to acknowledge Laborde's novel idea of an "oropharyngeal airway."<sup>49</sup>

In 1898, the Swiss surgeon Eugen Tschudy (1866 to 1938) performed an emergency intubation of the trachea, using a digital technique and inserting a medium-sized gastric tube for PPV. The patient, anesthetized with chloroform, had a giant goiter precluding tracheotomy.<sup>102</sup> Hewitt described "insufflation" as a valid resuscitation technique in anesthesia in his first textbook in 1893, but failed to do so in the second edition in 1901.<sup>55,103</sup>

Anesthesia exposed the provider to real-time emergencies and resuscitation situations. The airway management response was mostly untimely and unstructured, representing limited knowledge, local traditions, or the technique of the day.

### BAM Devices

One of the most artisanal aspects of anesthesia practice in this period was the proliferation of BAM devices. These were used to open the mouth and keep it open, relieve airway obstruction, and clear secretions. These were traumatic devices, and they compensated for imperfect anesthesia techniques or the administrator's lack of knowledge or skill. Wood wedges, screws, dental props with a piece of string attached to allow retrieval, and gags were part of the armamentarium (fig. 5). Hewitt supported "oral breathing over nasal breathing," achieved by the insertion of a mouth prop soon after consciousness had been lost. He consistently checked the patency of the nasal airway before induction and in 1903 advised the use of a mouth prop with every anesthetic.<sup>104</sup> This technique foreshadowed his invention of the oropharyngeal airway in 1908.<sup>105</sup>

In 1718, Lorenz Heister (1683 to 1758), a German surgeon, had introduced his very popular gag to open the mouth. It was followed by multiple variations, reviewed by Colt and Zuck (*e.g.*, Coleman, 1861; Mason, 1870; Probyn-Williams, 1901)<sup>106,107</sup> The tongue was retrieved with an artery or tongue forceps or digitally while protecting the finger with Langenbeck's Finger Armour (1893).<sup>108</sup> Multiple designs emerged (*e.g.*, Woodhouse Braine, 1886; Laborde, a combination of tongue forceps and retractor, late 19th century; Esmarch, 1895, Guy's Hospital; 1901; Championnière, 1903).<sup>107</sup> The tongue forceps remained indispensable to anesthesia practice until late in the 20th century.

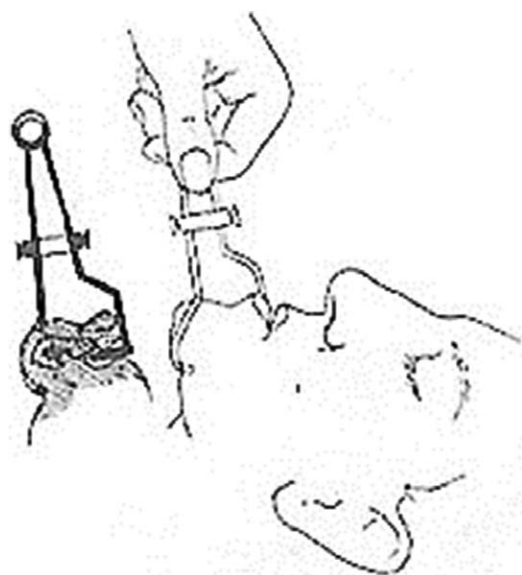
In 1890, James Foulis (Edinburgh) developed the glosso-tilt—a double-handed tongue depressor. The concave profile was inserted to move forward the tongue, hyoid, and epiglottis.<sup>109</sup> The need to free the hands for administration of anesthesia led to the invention of the tongue holder ("Zungenhalter") by Hans Leyden (1876 to 1934), which used straps to support a protruded tongue.<sup>110</sup> Gutsch developed a lower maxilla holder with a rubber pad placed behind the lower row of teeth, a wire ring under the chin, and a closable clasp; the mandible was thus drawn forward for a jaw thrust.<sup>85</sup> (fig. 6) In 1897, the German surgeon Carl Lauenstein (1850 to 1915) described the use of a nasopharyngeal



**Fig. 5.** Airway management devices. *Top*: model of upper and lower jaws gripping a screw-type mouth gag (introduced in the 1860s by Dr. Franz F. von Pitha, Germany). *Below right to left*: Hare combined mouth prop and tongue depressor (patented by William Hare, USA, in 1903), wooden mouth wedge (introduced in the 1860s by Dr. Franz F. von Pitha, Germany), Carmalt tongue forceps (cca. 1910), Heister-Mott mouth gag (introduced in Germany by Lorenz Heister in 1718 and in United States by Valentine Mott in 1829). Picture taken by the author at the Wood Library-Museum of Anesthesiology, Schaumburg, Illinois, with their kind support.

tube to provide a patent airway. His idea went unnoticed.<sup>110</sup> F. A. Nyulasy from Melbourne, Australia, described a headrest to support the head in a hyperextended position, improving operative conditions by dispensing with the assistant holding the head at the edge of the table.<sup>111</sup>

Mucus was the major cause of acute airway obstruction and late pulmonary complications. Often the sponge or towel used to clear secretions was overwhelmed by their amount. Pierre-Adolphe Piorry attempted tracheal suction by creating negative pressure with a sucker but had no followers.<sup>112</sup> The German surgeon Walther Kausch addressed pulmonary aspiration in 1903 with a "prophylactic" gastric drainage tube with a proximal inflatable balloon.<sup>85</sup> In edentulous patients, the unsupported lips and cheeks were stabilized with cotton wool placed between the gums and the cheeks or by maintaining *in situ* "well fitting false teeth."<sup>113</sup> In an attempt to improve direct observation of the patient's color for signs of impending asphyxia, a semitransparent glass (Vajna, 1893) and celluloid (Silk, 1894) FM with an inflatable cushion was developed. Kocher's wire-frame FM was designed for optimal application of a jaw thrust. It had



**Fig. 6.** Gutsch mandibular holder. Reprinted with permission from Brandt L, Bräutigam K-H, Goerig M, Nemes C, Nolte H. *Illustrierte Geschichte der Anästhesie*. Stuttgart, Wissenschaftliche Verlagsgesellschaft mbH, 1997, pp 156–9,<sup>85</sup> with kind permission for publication from the author Dr. Karl-Heinz Krauskopf (© KH Krauskopf).

two lateral symmetrical rigs for the thumbs, allowing the rest of the fingers to be positioned along the mandible.<sup>114</sup>

Airway management devices came in many forms and shapes, reflecting the lack of standardization during the artisanal period. In 1901, Hewitt advised the anesthesia provider to have the following readily available: instruments to open the mouth, a pair of tongue forceps, a small basin, a towel, a small piece of sponge, and instruments to perform tracheotomy.<sup>55</sup>

## Conclusions

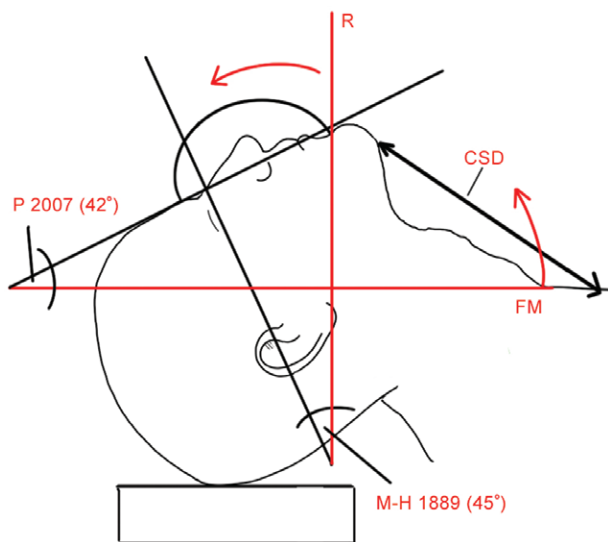
The birth of modern medicine, surgery, and anesthesia was part of the narrative that shaped the world in the 19th century. Slow progress in anesthesia in the first 50 yr of the century contrasted with major surgical advancements. However, surgery had hundreds of slow years before the barber-surgeon evolved into a professional. The slow development of anesthesia, paralleled by the slow progress in airway management, was inherent to the birth of a new discipline. In 1900, with the exception of the 32 unofficial anesthetists in London, the responsibility for anesthesia rested with the surgeon or general practitioner. Institutionalized anesthesia education, practice, and research were nonexistent.<sup>115</sup>

Poor anesthetic and faulty airway-management techniques resulted in hypoxic, hypercarbic, overdosed, and hypothermic patients with overt or silent pulmonary aspiration. Short surgeries, light anesthetics, and favorable demographics were needed to compensate for crude techniques. The average working-class Victorian man was 5'9 to 10" tall and 170 pounds (body mass index = 24.4); the average

woman was 5'3 to 4" and 120 pounds (body mass index = 20.6). Obesity was very rare. Industrial cigarette production did not begin until 1883, but already in 1903, Hewitt remarked that the "excessive use of tobacco" was complicating anesthesia by producing excessive secretion of mucus and suspended breathing.<sup>116,117</sup> Airway obstruction became a challenge when surgical procedures became longer and required muscular relaxation for successful completion. While PPV eventually lost its stigma of destroying the alveoli and was mentioned in textbooks as an option for artificial respiration, it was long kept at the fringes of resuscitation and anesthesia practice.

Airway obstruction research was limited to self-examination, clinical observation, and cadaver studies. The tongue was considered the main cause of obstruction, as it was readily observed and accessed. The Edinburgh School (Simpson, Syme, and Lister) popularized pulling the tongue forward in anesthetic emergencies; this became the first airway maneuver used in our specialty. Recent research has shown that in most subjects, lingual traction fails to clear nasopharyngeal (soft palate) and epiglottic obstruction.<sup>118,119</sup> While this conclusion is valid in the situation of modern fiberoptic intubation, in which the tip of the tongue is gently pulled in a vertical direction, extrapolating it to 19th century practice, when a tongue forceps was applied to the base of the tongue, pulling it forcefully over the lower incisors, is difficult. Pulling the tongue favored the oral route, bypassing soft palate and nasal obstruction, and also stimulated an obtunded patient. Surgeons strongly supported the use of the tongue forceps and tracheotomy. Just as today, soft palate and nasal obstruction were the least understood and addressed. The epiglottis was considered to obstruct the airway independent of the tongue (Howard) or together with the tongue (Foulis).<sup>79,109</sup> The simplistic but dominant concept of the tongue falling back and obstructing the airway took root early in the artisanal anesthesia era and has been perpetuated to this day.

Active airway maneuvers used to mobilize the tongue, hyoid, and epiglottis by manipulating movable bony structures (mandible and cervical spine) were well described by the last quarter of the 19th century. The original description of the two fundamental BAM techniques (jaw thrust and chin lift) as two-hand maneuvers without the use of a FM is valid today. The FM incorporated all its modern characteristics: symmetrical dome, connector, and soft margins or cuff. For decades, the FM was used only as a funnel for anesthetic delivery, while airway maneuvers were used independently as rescue interventions. FM seal and airway patency were unrelated concepts. Toward the beginning of the 20th century, the two concepts merged and produced a myriad of expressions representing practitioners' preference, experience, hand size, and the FM design. One finger (usually the fifth) was used to monitor the patient (swallowing, breathing, and pulse), thus generating different types of grip. Postural airway management methods (body drawn to the



**Fig. 7.** Chin lift-head extension with opening the chin-sternum distance (CSD). The maximum head extension measured on cadavers in 1889 by Martin and Hare (M-H angle ~45 degrees) using Reid's line (R) is functionally equivalent to the angle measured in awake volunteers in 2007 by Paal *et al.*<sup>120</sup> (P = 42 degrees) using a longitudinal line through a face mask cuff (FM). Illustrator: Stefan Maticoc.

edge of the table with the head hanging free, head extension with elevation under the shoulders) were adopted from resuscitation.

The artisanal period did not result in any standardization of airway-management techniques or devices, and it is difficult to gauge the spread of BAM knowledge at the end of the 19th century. The predicament of slow access to knowledge, imperfect inhalation techniques, and unknown or untimely airway maneuvers was the reality in many parts of the world. Bowles, an accomplished British airway expert, witnessed the effectiveness of the jaw thrust only in 1890 during his visit to Berlin. It is very likely that airway maneuvers were anonymously applied in many parts of the world, as providers used them instinctively as an expression of personal experience or anecdotal teaching independent of published literature.

Attempts to define airway maneuvers objectively used the chin–sternum distance and the head-extension angle. The maximum head-extension angle of 45 to 50 degrees, measured on cadavers in 1889 by Martin and Hare using Reid's line, is functionally equivalent to the angle of 42 degrees measured in awake volunteers with the head in neutral position in 2007 by Paal *et al.*<sup>120</sup> using a longitudinal line through the mask cuff (fig. 7) The latter was an attempt to implement objective markers in 21st century FM ventilation technique.<sup>82</sup> Today as in the 19th century, routine FM ventilation lacks objective markers.

The anesthesia candidates identified as “problematic” match today's predictors for difficult FM ventilation: obese, plethoric, thick-necked (“John-Bull type”), edentulous, bearded, with fixed neck and jaw, small mouth

opening, or overbite.<sup>104</sup> Hewitt acknowledged the importance of maintaining a free airway during anesthesia but deplored the poor airway techniques in use with a “tendency to induce [iatrogenic] airway obstruction.”<sup>55</sup> He called for anesthesia teaching and practice to provide greater safety to the public.

At the beginning of the 20th century, there were no answers for the problems of postoperative pulmonary complications, death related to anesthesia, protection of the airway, and safe anesthesia for thoracic, neurologic, and maxillofacial surgery. There was a discrepancy between what anesthesia was expected to do and what it was able to deliver: “The want of confidence in anesthesia is detrimental to surgery generally.”<sup>66</sup> The artisanal state of BAM was a limiting factor in the advancement of general anesthesia and surgery.

Airway management and general anesthesia were in need of a paradigm shift.

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## Competing Interests

I hold US Patent 6,651,661 B2 for the ergonomic face mask and receive royalties from The Tuoren Group, Menggang, Henan, China, for the ergonomic face mask product.

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