

# History of mouth-to-mouth ventilation

## Part 3: the 19th to mid-20th centuries and “rediscovery”

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The correct ideas of resuscitation were discredited, discontinued and then largely forgotten.

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Occasional recommendations for mouth-to-mouth ventilation continued through the 19th and early 20th centuries but it was well out of fashion and virtually forgotten.

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Rescue breathing by mouth-to-mouth expired air ventilation (EAV) was still being used to a degree in Britain towards the end of the 18th century,<sup>3-5</sup> as discussed in a previous article<sup>6</sup> (see Footnote 17). This was despite the Royal Humane Society (RHS) withdrawing its official endorsement in 1782, and instead promoting use of inflating bellows, or chest compression.<sup>4,5A</sup> The change was probably due as much to the perceived undesirability of expired air, with its “poisonous gas” CO<sub>2</sub> and reduced O<sub>2</sub> content (a viewpoint held among doctors and “philosophers”), as to aesthetic distaste for the procedure (among lay rescuers especially), for which the RHS had advised “interposing a handkerchief for delicacy”.<sup>9</sup> However, Charles Kite in 1787,<sup>10</sup> then John Herholdt and Carl Rafn in 1796,<sup>11</sup> had confirmed the efficacy of EAV.

Benjamin Howard<sup>12[p.316]</sup> observed that the 1802 report of the RHS listed action “to restore breathing” — not allowed to be effected by any form of EAV — as only sixth in its list of interventions in resuscitation. Instead, the RHS advised, “*Introduce the pipe of a pair of bellows (when no apparatus) into one nostril; the other with the mouth being closed; inflate the lungs*”. By 1812, the RHS was so set against mouth-to-mouth inflation, because of its belief that expired air was “poisonous” (“noxious and unfit to enter any lungs again”<sup>13</sup>), that should inflating bellows be unavailable, its annual report again recommended the surgeon practise alternating compression and relaxation of the abdomen, instead of mouth-to-mouth ventilation (MMV).<sup>4[p.6],5B[p.825]</sup> In its 1817 report, the RHS declared<sup>14</sup> “*expired air by the most*

### ABSTRACT

The start of the 19th century saw the enthusiasm of the previous one for mouth-to-mouth ventilation (MMV) dissipated. To inflate the lungs of the asphyxiated, the Royal Humane Society in the United Kingdom had recommended bellows since 1782. Principal determinants for change were aesthetic distaste for mouth-to-mouth contact and the perceived danger of using expired air, although MMV survived in the practice of some midwives. Following the 1826-9 investigations of Jean-Jacques Leroy d’Étiolles then François Magendie, all positive pressure ventilation methods were generally abandoned, after 1829 in France, and 1832 in the UK; but not chest compressions. During the next quarter century, rescuers lost understanding of the primary need for “artificial respiration”, apart from researchers such as John Snow and John Erichsen, until Marshall Hall’s “Ready Method” heralded the second half-century’s various methods of negative pressure ventilation. Some of those methods continued in use until the 1940s. Sporadic anecdotal cases of MMV rescues were documented throughout.

In the 20th century, inadequate mechanical inhalators were also tried from 1908, while obstetricians devised indirect methods of expired air ventilation (EAV). Anaesthetists in the 1940s, such as Ralph Waters, Robert Dripps, and the pair, Robert Macintosh and William Mushin, described the usefulness of MMV, and James Elam was “re-discovering” it. Following World War II, “Cold War” concerns stimulated research at the Edgewood Medical Laboratories in Maryland in the United States into the possibilities of MMV, and Elam et al confirmed and expanded on brief experiments at Oxford (United Kingdom) on the efficacy of mouth-to-tube EAV. Studies, 1957-9, by Archer Gordon, Elam and especially Peter Safar resulted in the resolution of previous airway problems, established the primacy of MMV, and incorporated it into an integrated system for basic cardiopulmonary resuscitation. Ready adoption of MMV in the US was followed by worldwide spread, especially after endorsement from the 1962 international symposium at Stavanger in Norway. However, already there were occasional rumblings of reluctance to perform MMV. In this article, I consider MMV also in the context of other ventilatory modes for resuscitation.

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**Footnote 1.** In the two previous articles in this series,<sup>6,8</sup> I used the phrases “expired air ventilation” (EAV) and “mouth-to-mouth rescue breathing”. I note the 1959 preference of the American Medical Association’s Council on Medical Physics for “expired air inflation”,<sup>7</sup> and, although that term seems perhaps more apposite than expired air ventilation, the latter has become established and will be continued with here. As the term “mouth-to-mouth ventilation” is widely used, I have adopted it for this article instead of “mouth-to-mouth EAV” as used previously. ♦

healthy is not pure air but chiefly carbonic similar to what arises from burning charcoal"; hence, exhortations from bystanders for rescuers to apply EAV to an apparently dead person were properly to be ignored.

The conclusions reached about the later years of the period 1774–1811 by Sir Arthur Keith, in his 1909 study of RHS records,<sup>5C[p.897]</sup> seem equivocal about how much EAV was then being used. Keith<sup>5B[p.828]</sup> cites an account from the RHS's 1802 report of the presentation of a Society medal (which is also listed in the RHS Medals Index for 1803<sup>15[p.233]</sup>) to "Mrs Ann Newby", the matron of the City of London Lying-in Hospital, for 500 successful neonatal resuscitations. (Does Peter J Bishop's calling her "Ann Newly"<sup>4</sup> represent a typographical error?) Keith had "*reason to believe that mouth-to-mouth inflation was part of the means*". At his time of writing (1909), when Edwardian opinion strongly favoured arm movement/chest compression techniques for artificial ventilation, he could well have given a more positive boost to the EAV method if he had been able to confirm that MMV was the likely method used — rather than presume it was. (Also, see Footnote 2<sup>16-19</sup> re **François Chaussier** [1746–1828].)

An anonymous **Glaswegian treatise**<sup>20[p.26, Exhibit68]</sup> from 1823 advocated MMV for rescuing "Persons residing at a Distance from Medical Assistance", as "this method is by far the simplest and most ready". Its author anticipated some criticism of the "indelucacy" of MMV, and that the air being used was bad — which the treatise advanced as "rather a supposition than a reality".

### The decline of artificial support for breathing

In France, artificial ventilation was by MMV, or from inflation through a nasal tube by bellows ("*de préférence*") or by mouth ("*ne souffler avec la bouche que lorsqu'il est impossible de faire autrement*"),<sup>21</sup> combined with chest compression.<sup>21,22[p.27]</sup> In Paris, February 1826, **Jean-Jacques**

**Leroy d'Étiolles** (1798–1860) presented his animal and postmortem experiments to L'Académie des Sciences,<sup>23,24</sup> demonstrating that animal and human lung rupture (or at other times "emphysema") could follow enthusiastic or careless overinflation with bellows. The reaction ensured, ultimately, the end of resuscitation by MMV and all positive pressure efforts to inflate the lungs and, in consequence, tracheal intubation as well. **François Magendie** (1783–1855) and **Andre-M-C Duméril** were charged to investigate his claims and, in 1829, confirmed Leroy's work to L'Académie.<sup>25</sup> Ralph Waters et al<sup>16</sup> stated in an outline history of intubation — for which they did not provide references — that, after investigating Leroy's studies, Duméril and Magendie "*reported that the damage done by attempts at intubation far outweighed its advantages*". The source enabling such an attribution is not provided, and I have not yet seen other writers confirming it, nor can I find support for it in Magendie's *Rapport* itself. Amongst what Magendie did state was his opinion that, physiologically speaking, he "viewed" bellows as undoubtedly superior to MMV.<sup>25[p.104]</sup>

These reports caused the French Académie to condemn bellows (possibly laryngeal tubes also?), despite Leroy's attempts to submit his "safety bellows set", which would allow grading of the inflating pressures by the victim's age.<sup>17[p.36]</sup> Leroy alternatively proposed simultaneously compressing the chest and abdomen of the patient placed supine.<sup>5A-B,13,22,23</sup> L'Académie also rejected another of his interventions, the split-sheet method of pulling alternately on each crossed end of a bandage-sling under the chest of the (supine) patient, to express air by compression exerted on the lungs; release of the sling allowed re-expansion from elastic recoil of the chest wall.<sup>14,22[p.27]</sup>

In England, in agreeing with L'Académie, the RHS gave up on recommending airway tubes and bellows by 1832,<sup>4,26</sup> advising warming and friction instead — but it did *not* reinstitute EAV. Instead, "artificial respiration" could be supplied by external manual compression to the chest (plus or minus to the abdomen) of a supine victim; or perhaps using **John Dalrymple's** 1831 version of Leroy's method, which employed long bandages to roll the supine body from side to side, compressing the chest.<sup>4,5B,26</sup> The RHS recommended this method in 1833.<sup>5B</sup> Sir Astley Cooper had already used direct ribcage compression with subsequent chest expansion by recoil for perhaps two decades (see Alexander H Stevens' letter, 1812, as cited by K Garth Huston, 1989<sup>27</sup>).

By 1835, the RHS had established their new Receiving House in London's Hyde Park, principally for those accidentally drowned.<sup>28</sup> On that year's Christmas Day, with crowds of skaters (? "thousands", as the Medical Gazette stated<sup>29</sup>) on the ice of the Serpentine in Hyde Park, the ice gave way and "above seventy" fell into icy water. Diana Coke's

**Footnote 2.** At the start of the 19th century in France, **François Chaussier** introduced metal, curved, translaryngeal tubes blindly into neonates, attaching an inflating bag to resuscitate them (1806<sup>16</sup> or 1807<sup>17</sup>). **George M White**<sup>18</sup> attributed to **William Perry Northrup** a statement that **Chaussier** used expired air ventilation (EAV): "the operator then blew down the tube intermittently", but that is not contained in either of Northrup's two 1894 papers, which **White** supplied for references. In a 1780 memorandum, the same **Chaussier** had condemned EAV because it was harmful to animals and lethal from its fixed air [CO<sub>2</sub>], preferring to resuscitate neonates with the simple, clean, bag and face-mask combination he designed.<sup>17</sup> It is not clear that **Leslie Rendell-Baker's** statement "inflation ... was carried out by the operator blowing down the broad end of the [**Chaussier**] tube" confirms that **Chaussier** himself returned to practising EAV, or whether that applied only for other practitioners; but a later letter from him<sup>19</sup> makes it seem so. Later 19th century French obstetricians continued with mouth-to-tube practice.<sup>16,17</sup>

history of the RHS Receiving House<sup>28[pp.35-7]</sup> clearly details the events from the minutes of the Society's meetings on 29 and 31 December. The episode is renowned for "fifteen bodies all at once, and under one roof [of the Park's RHS Receiving House, 50 yards (= 45 metres) from the accident site<sup>28</sup>], to be attended by seven medical men," after 16<sup>28</sup> (not 15, as some stated<sup>29,30</sup>) were rescued "in a state of suspended animation". The survival of not more than seven victims caused soul-searching.<sup>28-30</sup>

Diana Coke's selections do not indicate that any specifically respiratory treatments were used for the asphyxiated, only the general measure of immediate warm baths.<sup>28,29</sup> That the mainstay of treatment for drowning was warming is exemplified by "... *the first body, in fact, was in a warm bath* ["about 100° (F)<sup>31,32</sup> (= 38° C)] *in two or three minutes after submersion, and the whole fifteen were under treatment in no very long time*". The minutes proclaimed, "*in every case wherein there was the smallest spark of life on entering the Receiving House, the Resuscitative process was successful ...*".<sup>28[p.36]</sup>

Two years later, in 1837, the RHS formally abandoned EAV<sup>4</sup> and bellows,<sup>22</sup> but offered no more effective ventilatory substitute than Dalrymple's method.<sup>4,5</sup> By the Society's 1840 report, the eminent medical members of the RHS committee (Dalrymple and, as below, Brodie and Woolley) found that "*the period in cases of asphyxia when artificial respiration might be successful is very short and scarcely more than momentary, and, as it but rarely happens that such measures can be supplied at the precise moment, artificial respiration should be considered as a secondary means*".<sup>31[p.41]</sup> John Erichsen later explained that this meant secondary to the primary actions of mouth and nostril cleansing, heat, brisk friction and inhaled ammonia.<sup>31[p.55]</sup> Because of the great influence of the RHS gentlemen, Erichsen understood that artificial respiration "*is but rarely had recourse to at the institution in Hyde Park*".<sup>31[p.40]</sup> Antipathy to the very notion of artificial respiration is typified by the attitude of the influential **Sir Benjamin Brodie** (1783–1862), who had been dogmatic about its limited usefulness since 1821.<sup>13</sup> He declared in the RHS report for 1842, "*It appears to me there are very few cases in which this method (artificial respiration) is really applicable*".<sup>12[p.323]</sup> In December of the previous year, 1841, John Snow, in criticising this attitude (while invoking John Hunter),<sup>32</sup> had told the Westminster Medical Society that he found such an opinion about artificial respiration from two influential RHS members "perfectly astounding", as it was the proven "*measure which might be useful at a later period in asphyxia than any other*".<sup>32</sup>

Generally, it was considered that to allow recovery, "drowning" time not over 4<sup>31[pp.35,53]</sup> or 5<sup>30</sup> minutes submerged was critical, lest the heart stopped; when, declared

Brodie, "*it would be impossible to restore its action by artificial respiration*".<sup>32</sup>

**In the United Kingdom, for at least the two decades from 1837, rescuers strove to resuscitate more or less without effective artificial ventilation until Marshall Hall tried a new method of improving treatment at the resuscitation scene.**

If no air was allowed to be blown *into* the lungs, one alternative enthusiastically described in 1839 by **John Hancock**<sup>33</sup> was of "exsugation" (a word the Oxford dictionaries do not recognise; it would appear to be derived from the Latin *sugere*, to suck). Hancock himself reported that exsugation, or "strongly sucking at the nostril of the patient" together with closing the subject's mouth, was a simple but rather repulsive process. His series of two instances of recovery, with one victim "taken out of the water cold and quite inanimate", unsurprisingly was not followed by a flood of similar reports to *The Lancet*. (But later there is an echo of the notion of suction stimulating the Hering–Breuer reflex in the apnoeic patient, in Cecil Drinker's 1945 monograph).<sup>34[p.85]</sup>

### John Erichsen's asphyxia studies, 1845

A reliable indication of the RHS's ideas about respiratory resuscitation in the 1840s comes from surgeon John Erichsen's 1845 report to the British Association for the Advancement of Science, of his findings from an *Experimental enquiry into ... asphyxia*.<sup>31</sup> As above, he refers to the Society's 1840 report<sup>31[p.41]</sup> describing the medical opinion (especially Brodie's) that artificial respiration should be considered only a secondary method; and he quoted **George Woolley**, surgeon to the RHS Receiving House, as advocating that the House "*employ artificial respiration in all those cases in which the respiratory actions are not naturally restored on taking the sufferer out of the water, or on placing him in the hot-bath*".<sup>31[p.41]</sup>

Erichsen dismissed MMV itself, as "*Inflation from the mouth of an assistant is objectionable, as air once respired is not fitted for the support of animal life*".<sup>31[p.49]</sup> And although calibrated bellows, "*if furnished with Leroy's trachea pipes, or what is better, with nostril tubes, may be safely employed by medical men*",<sup>31[p.49]</sup> he saw the split-sheet method of either Leroy or Dalrymple as efficient and the safest means. Otherwise, he favoured chest compression techniques. In animal experiments, although moderate "*insufflation of the lungs with atmospheric air can re-establish circulation after it has entirely ceased*" (his finding was to be denied by Brodie), "*it is absolutely necessary to compress the chest and abdomen pretty forcibly, each time that a fresh quantity of air has been introduced, as otherwise a dangerous degree of distension of the lungs*

Figure 1. John Snow



In the early 1840s, when eminent personages in the Royal Humane Society dismissed artificial ventilation as of secondary importance for resuscitation from drowning, John Snow strongly argued it was the proven “measure which might be useful at a later period in asphyxia than any other”.<sup>32</sup> ♦

might be produced”.<sup>31[p.54]</sup> Erichsen’s best animal recoveries had come from inflating with oxygen, not with “pure air”. To administer O<sub>2</sub> — which would be feasible only at such locations as inside the 11 RHS houses or stations in London — he invented a graduated syringe-gasometer combination (20 cubic inches [= 330 mL] and 18 gallons [= 80 L], respectively), delivering an inspiration of not greater than 15 cubic inches (= 250 mL) of O<sub>2</sub> to avoid overdistension (he saw “an ordinary inspiration” as drawing in about 22 cubic inches [= 360 mL]).<sup>31[p.53]</sup> This was to be “entrusted to none but a medical man”.<sup>31[p.55]</sup> Erichsen quoted three clinical successes of his own and “several” of others.<sup>31[p.55]</sup>

In summary, for the resuscitation of a victim Erichsen re-established experimental validation for:

- artificial ventilation (as exhorted previously in the later 18th century by, for example, John Hunter and Charles Kite<sup>10</sup>) as the only certain means available; its “first importance” needed immediate application — but not by MMV; and

- oxygen (as strongly advocated in the late 18th century by Andrew Fothergill<sup>35</sup>) as the best resuscitating agent. This was advised for “desperate cases”<sup>31[p.53]</sup> (submersion time over 4 minutes).

Although the RHS awarded him the 1845 Gold Medal for this report, it did not take up his advice. Erichsen was partly assisted by Professor “Dr Sharpey”.

### EAV and MMV in the community

It should not be taken from all this that EAV was never used for resuscitation, even though it did not have the “official endorsement of any medical organisation”.<sup>36</sup> Dr Terry of Northampton,<sup>12[p.318].37</sup> 1837, resuscitated two stillborn babies with EAV by breathing into their nostrils — which Peter Karpovich called “a new method” for then<sup>22[p.27]</sup> — alternating with compressing the chest to facilitate expiration.

In *The Lancet*, 1841, Thomas Smethurst<sup>38</sup> documented MMV in his remarkable rescue of a 2-year-old, “quite dead” by drowning: by “breathing warm air into the mouth and lungs”, after reaching the victim late — 10 minutes after she fell 17 feet (= 5 m) into a well, where she was located on her back but submerged. He could describe her as “perfectly recovered” a week later. A Dr Pettigrew, 1841,<sup>32[p.212]</sup> applied “artificial respiration by the mouth [what to, mouth or tube?] and frictions” to a patient immersed for 25 minutes (outcome not stated).

Four months earlier in the same journal, C Searle<sup>39</sup> had listed what he saw as the necessities for resuscitation. After use of the warming bath, he advised, “Secondly. The lungs to be inflated with air, at the temperature of at least 98° (= 37°C). Like so many case-writers during the rest of the 19th century, he did not specify what he meant when mentioning “artificial respiration”. Thus, was Alfred Poland’s 5½ hours of artificial respiration<sup>40</sup> — following an immediate tracheotomy for a scalded glottis — delivered by chest compressions, with “a mechanical expiration”, or by EAV (or bellows) through “a gum elastic catheter in the canula [sic]”? The concept of the body needing normothermia for survival after “apparent death” was at that time strongly held, so warming was the mainstay of treatment; with use of bleeding, galvanic electricity, saline injection, inhalation of alkaline vapours, etc.<sup>31[p.55]</sup>

Francis Sibson’s 1848 EAV method of blowing into a tube attached to a modified chloroform mask did not establish this mode as a regular inflating technique.<sup>41</sup>

### John Snow (1813–1858)

In 1841, while still a “surgeon–apothecary, or general practitioner in emerging parlance”,<sup>42[pp.3-6]</sup> but already with

five research papers published,<sup>42[p.91]</sup> John Snow (Figure 1) had a Soho practice involving many obstetric deliveries. Wishing to be able to treat any asphyxiated newborn, or even stillborn babies, he strove to increase his resuscitative options. Although “*Several eminent authors on midwifery recommend breathing into the lungs of the child, if other means are not at hand*”, Snow’s opinion was that “*not much good can be expected from a measure which would undoubtedly suffocate a living child*”.<sup>43[p.225]</sup> That was probably based on his acceptance of Allen and Pepys’ erroneous finding that “*air which had been once breathed contained about 8 per cent of carbonic acid*”,<sup>43[p.225]</sup> and his own experiments with 5% and 3% CO<sub>2</sub>.<sup>32</sup> In the 1840s, fear of CO<sub>2</sub> was quite prominent; and Snow believed it “*exercised a deleterious effect independent of the diminution of oxygen*”.<sup>44</sup> He was aware that “*some children had been restored by inflating the lungs with the breath, but [he considered] any inflation, however imperfect, with fresh air, must be much superior*”.<sup>32[p.212]</sup> Ordinary bellows, “*although much better than blowing with the breath*”, were also considered dangerous lest overinflation occur, so he devised a safer breathing aid for neonates.<sup>43[p.225]</sup> Snow had Mr J Read manufacture for him the “*useful auxiliary*”<sup>43</sup> of a neonate-sized version of the 1838 Read and (Dr James) Johnson system of simultaneously inflating–deflating, paired syringes, to deliver air with supplemental oxygen. (The oxygen would be “*generated [on site!] ... in a few minutes*”).<sup>43[p.226]</sup> But it does not appear to be recorded whether Snow himself used his device for artificial ventilation.<sup>45</sup> By 16 October 1841, amid some dissent about his stillbirth statistics,<sup>42[p.93]</sup> Snow was advising a Westminster Medical Society meeting to employ his device — but only after a preliminary clearing of the airway.<sup>32</sup> Snow also foresaw other artificial respiration uses for his device. But for adult asphyxia, he advised warmth only *after* respiration was restored, contrary to the ideas of the RHS.<sup>32[p.212]</sup>

Two recent accounts<sup>42,45</sup> emphasise Snow’s careful scientific approach and his significant investigations into asphyxia, well detailed in his own accounts.<sup>32,43</sup>

### EAV for the newborn

One could expect resuscitation to have been used in the 19th century practice of competent midwives. Thus, in 1816, the RHS followed up the award of a medal to Mrs Newby with one for her successor, identified by Carolyn Williams from the Medal’s Index, 1817, as Mrs Wigden<sup>15[p.233]</sup> (not Keith’s “Widgeon”,<sup>5B</sup> see Footnote 3); then another medal to her daughter Mary Wigden in 1857, both of the City of London Lying-in Hospital. Keith cites the pair’s resuscitations; but apart from saying that “*Mary Widgeon’s*” methods were the same as her late mother’s,

he does not indicate EAV, or anything more than “*chiefly warmth and friction*”. How often they employed MMV is not stated. But the 1856 records of St George’s Hospital, London, show official recognition of its Matron’s success in “*saving of the lives of over 300 new-borns*” by what AV Neale, 1963, called her “*ingenious and effective method of resuscitation — mouth-to-mouth technique*”.<sup>46</sup>

John Wills had *Lancet* documentation<sup>47</sup> of his successful 8 July 1855 resuscitation by EAV of a stillborn child, in whom “*evidently life was quite extinct at birth*” after 12 hours’ natural labour. Wills breathed for 30 minutes into the newborn’s lungs through an extempore, intralaryngeal tube fashioned from a goose quill.

### EAV and resuscitation for collapse under anaesthesia

After Hannah Greener’s pathetic death from anaesthesia — the first in Britain; it is recorded in the Register of Burials<sup>48</sup> that she “*died from effects of chloroform*” on 28 January 1848 — it became obvious there was a new area of need for resuscitation. Now, however, when anaesthetics could cause breathing or cardiac arrest, it was in the context of having an attending medical practitioner or dentist to hand. In the common practice of not having a doctor attending childbirths, there usually was a midwife to render immediate intervention — if they were so inclined and capable. But anyone closest to a drowning victim was likely to be a layperson.

It is informative to study John Snow’s 1858 collection of 50 worldwide “*fatal cases of inhalation of chloroform*”,<sup>49</sup> to see what artificial ventilation method medical practitioners were using to attempt lung inflation after arrest. Snow could record that actual artificial ventilation efforts had been described as taking place in only 18 of the 50 cases reported for him (plus, also, in two further alleged chloroform cases and for two amylene deaths). Mouth-to-nose attempts were made in two of the 50 patients (Cases 23 and 34) while MMV was employed in just four patients (Cases 9, 41, 42 and 44). Some of these were accompanied by compressive efforts to empty the lungs. But with Erichsen’s patient (Case 42), his applying MMV “*did not appear to succeed well and was almost immediately substituted by the more usual mode of artificial respiration, by compression of the chest, which was kept up most vigor-*

Footnote 3. Sir Arthur Keith refers to Mary as a Mrs Widgeon<sup>5B</sup> (the “*Mrs*” possibly an honorific title for a midwife). In a 2001 communication<sup>15[p.233]</sup> with the RHS Secretary, Major General Christopher Tyler, Carolyn Williams established Wigden as the correct spelling of this woman’s surname; and also that Sir Arthur Keith’s “*Mrs Ann Newby*” could be seen from the RHS’s Medal Index of 1803 to have the given name of June, so she was Mrs June Newby. ♦

ously".<sup>49[p.182]</sup> Compression of the chest was the mode recorded for three patients (Cases 3, 12 and 43) and was presumably applied for the six cases of "artificial respiration", unspecified (Cases 25, 28, 32, 40, 46 and 47; plus for the alleged case of 1852). "Artificial respiration" (presumably with bellows) was applied through a tracheal opening in Case 31 and, after a time, in Case 32.

Only three of these 50 cases were recorded as taking place after the significant *Lancet* date of 12 April 1856, with its publication of Marshall Hall's landmark paper<sup>50</sup> introducing his "Ready Method" of artificial ventilation. These three all had artificial ventilation supplied by the use of Hall's new method, as also did the 1857 case of alleged chloroform death, and the two cases of amylene death, including Snow's own case.

In many attempted resuscitations, all later than Case 31, the tongue was mentioned as grasped and pulled forward, for example with "catch forceps", in appreciation of the need for patency of the airway. Snow also recorded in his book that all the cases of reported recovery after suspended animation from chloroform had been restored *with* artificial respiration in their resuscitation.<sup>49[p.252]</sup> He did not describe the methods used but states that **M. Ricord** "*succeeded in restoring two patients who were in a state of suspended animation [which Snow considered was probably apnoea without cardiac arrest] by mouth to mouth inflation of the lungs*". This must have been sometime between 1847 and 1858.

Despite the success of MMV that Snow recorded for some of the above cases, in 1858 he believed that "*The most ready and effectual method of performing artificial respiration is undoubtedly the postural method, introduced by Dr Hall*".<sup>49[p.260]</sup>

In 1853, *The Lancet's* Foreign Department recorded that **M. Boinet** used "M. Ricord's method" of MMV, eventually successfully, to save a woman in arrest after chloroform for a forceps delivery, and at first declared dead following 5 minutes of other efforts.<sup>51</sup>

### MMV displaced by negative pressure ventilation

For resuscitation meantime, in both the lay world of 1837–1856 and the non-anaesthetic medical scene after 1846, it seems that artificial ventilation was well nigh forgotten, despite the arguments of Snow and Erichsen. To what extent that deficiency also included MMV is not recorded, but from the paucity of documentation it seems very likely to have been so. Peter Bishop points out that when **Marshall Hall** (1790–1857), burst onto the resuscitation scene, understanding had deteriorated to the extent that it was "*at a time when the Society [the RHS] omitted any*

*mention of artificial respiration from its instructions*".<sup>4</sup> Hall was highly critical,<sup>50</sup> emphasising:

- the need for immediate action ("not a moment should be lost");
- the effect of the supine position causing the disaster of the tongue falling back and obstructing the glottis — allegedly "never before pointed out" (overlooking Edmund Goodwyn, 1783, and Anthony Fothergill, 1794);<sup>35</sup> and
- his description of a new mode of effecting artificial inflation of the lungs — the Ready Method.

Hall's Ready Method of artificial ventilation<sup>50</sup> had the patient placed prone, from which position he or she was turned repetitively side to side (a cycle of back pressure to the prone patient — patient turned onto the right side — turned prone, then back pressure — turned onto the left side ...).

Hailed enthusiastically and adopted for resuscitation, Hall's method was initially intended principally for drownings, with successes being quickly recorded, but was then applied elsewhere. For example, on 11 January 1857, **Charles Blades** spent several hours applying the Ready Method for a child aged 13 months, accidentally narcotic-poisoned (no detectable pulse or breathing), with subsequent recovery.<sup>52</sup> As mentioned, Snow employed Marshall Hall's manual method of artificial ventilation, 7 April 1857, for his own single case of fatal cardiac arrest during amylene anaesthesia. And Snow's endorsement of Dr Hall in 1858 — made despite known previous successes of MMV — has already been quoted.<sup>49[p.252]</sup>

Hall's method was challenged 2 years later by the method which **Henry Silvester** first tried successfully after the forceps birth of a newborn, given up as apparently quite dead when initial resuscitative efforts failed.<sup>53</sup> Abandoning Hall,<sup>22[p.39]</sup> the RHS officially adopted Silvester's arm-lift/chest-pressure supine method in 1861,<sup>58[p.826]</sup> and it was used almost universally for resuscitation for the rest of the 19th century<sup>22</sup> (see Footnote 4).

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**Footnote 4.** *As an indication of the limited adequacy of manual NPV (negative pressure ventilation) methods, the search continued for a better method — such that over a further 100 NPV manual arm-chest methods were put forward (see Karpovich's Table 2<sup>22[pp.162-811]</sup>) — until mouth-to-mouth ventilation became firmly re-established in the later 1950s. The techniques most favoured other than Silvester's supine method were Benjamin Howard's "Direct Method" of 1868 (also a supine method), Edward Sharpey-Schäfer's prone-pressure method of 1902, and Holger Nielsen's 1931-2 prone methods of arm-lift (for inspiration) with shoulder pressure (for expiration).<sup>22</sup> Before Nielsen, Karpovich's summary was "Europe, in general, remained Silvestrian, and England and the United States were definitely Schaferian".<sup>22[p.62]</sup> ♦*

### MMV for Abraham Lincoln

An MMV resuscitation that took place on Good Friday (April 14) 1865 is renowned for the eminence of the apnoeic subject; but it also raises questions. It was apparently unknown until the revelation 44 years after the event that, after Abraham Lincoln was shot in the head, he received MMV attention.<sup>54-58</sup>

The resuscitator was 23-year-old **Charles Augustus Leale** (1842–1932; Figure 2), at the time an MD graduate of only 2 months' standing but a commissioned officer in the Medical Department of the US Army. On that fateful evening, he had gained the last seat at Ford's Theatre, Washington, DC, for a presentation of *Our American cousin*, which the Lincolns also attended (see Footnote 5). The fullest medical account is Leale's own from 1909, quoted from below.<sup>54</sup>

After the assassin's shots rang out (possibly at about 22:30), Leale, also in the dress circle, vaulted over seats to gain entry into the President's box. Finding Lincoln pulseless and "his breathing hardly evident", he digitally cleared a clot from the head entry wound. (Leale's later accounts indicate he attached great importance to blood clot in the skull wound being likely to soon cause fatal compression of the President's brain.) Leale then referred to the President's breathing for the first time, by having thoughts about "apnoea" and "to revive by artificial respiration". "As the President did not then revive ... [he, Leale] ... made a free passage for air to enter his lungs"; then, with two assistants having now entered (Dr Charles Taft followed by Dr Albert King), with their help he supplied artificial ventilation by a variation on the Silvester manoeuvre. "... a feeble action of the heart and irregular breathing followed"; so Leale, then "convinced that something more must be done to retain life ... leaned forcibly forward directly over [the President's] body, thorax to thorax, face to face, and several times drew in a long breath, then forcibly breathed into his mouth and nostrils [all, together?], which expanded his lungs and improved his respirations .... And saw that the President could continue independent breathing and that instant death would not occur." With Mr Lincoln now breathing irregularly, and his heart beating feebly, Leale then assisted with transferring him to the hotel, where the President died at 07:20 h next morning. Leale described these events fully in his 1909 account, and others quote from it in much more detail than I have.

**Footnote 5.** *The account* The resuscitation greets by George Sternbach et al<sup>57</sup> states Leale was "specifically assigned" to attend the theatre. Leale's 1909 statement<sup>54</sup> indicates that he went there from his "intense desire again to behold his [President's] face"; he was off-duty and in civilian clothes, "after the completion of [his] hospital duties". ♦

**Figure 2. Charles Leale**



*Dr Charles Leale applied mouth-to-mouth rescue breathing to a stricken President Abraham Lincoln, "which expanded his lungs and improved his respirations .... And saw that the President could continue independent breathing and that instant death would not occur".* ♦

Dr Charles S Taft, who joined in to assist Leale, gave no details of the resuscitation in his 22 April 1865 account in the weekly *Medical and Surgical Reporter*.<sup>58</sup> It appears Leale may well not have produced his own formal written statement until sending a letter to Dr Benjamin Butler in 1867 (and thus the 1867 Congressional Assassination Committee), basing it, he said, on notes he wrote "a few hours after leaving his [Lincoln's] deathbed". But he did not mention having used MMV.

Some questions come to mind:

- How did it happen that Leale was inspired to supply such a treatment so out of favour, hence presumably little known? (See Howard's 1871 American comments on EAV, below.<sup>12(p.345)</sup>)
- Did Leale's knowledge arise from US medical students at that time being taught MMV during their training? In which case, are there still US medical school records showing that?
- Was it an established army procedure for battlefield resuscitation (possibly detailed in army medical manuals)

which had made MMV known to Leale? Do memoirs exist indicating that MMV could have been performed during the Civil War?

- Was MMV then better known and utilised more than we can tell from contemporary medical writing (eg, Howard's, 1871<sup>12</sup>)?
- As the shy and retiring Leale achieved a significant result with his MMV, why did he not mention it in his earlier reports, when he could have obtained valuable publicity for it; then unexpectedly first mention it in 1909, before the Commandery of the State in New York? However, Charles Leale's own account testifies that emotionally, he was tremendously affected by the part he played "that fateful evening", and that after Lincoln's funeral he received a religious-type inspiration to "Forget it all". Leale described that fully in his narrative of "Lincoln's last hours", later printed as a booklet but also available online.<sup>54</sup>

Yet, supplementary to Leale's account it has been indicated that MMV was sometimes employed. **Benjamin Howard**, 1871,<sup>12</sup>[p.345] while himself an innovator of an arm-chest method, was still describing the technique for "insufflation" (MMV in other words) as "of decided value" for the stillborn and not a difficult procedure for children if carefully practised; but "*in adults however, it is so rarely practicable as to be scarcely worth our consideration*". The reader may be interested to note that, in 1871, he was still advising jugular venesection after the "apoplectic form of apnoea" from hanging.<sup>12</sup>[p.345]

### The later 19th and early 20th centuries

MMV resuscitation survived in obstetrics, though Sir Francis Champneys, 1887, in Britain, raised the spectre of infection risk from EAV by recording 12 cases of newborn infants infected by a tuberculous midwife.<sup>59</sup> Ostensibly, from 1856, both EAV and artificial ventilation by bellows were more or less abandoned, the latter until 23 July 1887, when **George Fell** in Buffalo (NY) re-introduced — but could not firmly re-establish — IPPV (intermittent positive pressure ventilation) into resuscitation, and later, anaesthesia. IPPV was first administered for 2½ hours for a patient with morphine/chloral poisoning,<sup>60</sup> by foot-bellows with tubing and a valve to a hastily inserted tracheotomy tube (then on later occasions, to a face-mask instead<sup>60,61</sup>). But Fell seems to have failed to recognise the EAV concept: when his inflating bag collapsed during a prolonged resuscitation for morphine poisoning in 1898 (525 000 bellows movements at a rate of 100–120 per minute, he said!) he was "almost unnerved", the patient seemed "doomed to certain death" as three alternative means tried (two old bags and

then a bicycle pump) all failed, until a sound replacement was finally located.<sup>62</sup>[p.171]

An occasionally quoted<sup>5C</sup>[p.895],<sup>22</sup>[p.50],<sup>63,64</sup> resuscitative manoeuvre of anaesthetists<sup>5C</sup> without EAV, gaining attention about this time, was **J-V B Laborde's** 5 July 1892 method of "regular rhythmic tractions on the tongue, which 'alone often sufficed to restore respiration'".<sup>64</sup> Laborde's initial success was described for two "drownings",<sup>64</sup> but Arlo Hermreck claimed that there were 63 successful resuscitations using this technique.<sup>63</sup> W Freudenthal recorded a modification, applying direct irritation of the epiglottis.<sup>64</sup>

Yet, I have been able to find little mention of MMV around the 1900 period in the medical literature, or in a few midwifery textbooks from the first half of the 20th century. However, MMV did receive at least three publicity boosts early in the 20th century.

First, in 1906, Dublin throat surgeon **Robert Woods** presented his arguments — if hardly accompanied by much in the way of actual evidence — for the re-introduction of EAV into anaesthesia and resuscitation, as "*the mouth-to-mouth or nose method gives the patient the best chance*" (he was discussing cases of syncope under chloroform). Of four patients he mentioned, two died despite his use of "Sylvester's" method.<sup>65</sup> His paper seems to be quoted frequently, presumably for its foresight rather than useful data.

Secondly, **Charles Leale** described his single but noteworthy case of MMV in 1909.<sup>54</sup>

Lastly, in what he described as the first evaluation of RHS records, **Keith's** Hunterian Lectures of 1909<sup>5</sup> thoroughly documented the continuing history of artificial ventilation: as it had been practised by the Amsterdam Humane Society which started with MMV; then by the RHS since 1774, successively by MMV and bellows methods of PPV, and then by manual NPV methods. Keith concluded:<sup>5C</sup>[p.899] "*My mind is also open to the conviction that the ancient method of mouth-to-mouth insufflation with expiratory compression of the chest may not prove more effective than either*" the Silvester or the Schäfer NPV method. But then he gave a major boost to MMV practice by stating, "*at least, if it should happen that I may be found in an apparently drowned condition I sincerely hope that my rescuer will apply this method to me as my first aid*".

Otherwise, there is a dearth of quotable information on MMV from the first quarter of the 20th century.

### The 20th century: EAV and the newborn

Although Clarence Heald's article in the *Journal of the American Medical Association*, 1918,<sup>66</sup> rated MMV by "insufflation" as one of "the classic methods of artificial



respiration in asphyxia neonatorum", he found serious objections, such as the liability of lung rupture, the operator transmitting infection to the child, fatigue, futility, and others (oxygen deficit, carbon dioxide loading) that dated back to the 18th century. So Heald devised his own system of manual PPV apparatus for apnoeic newborns.

The year 1930 had seen the cautionary reporting of a fatal pneumothorax attributed to MMV,<sup>67</sup> and the *American Journal of Obstetrics and Gynecology*, 1933–1946,<sup>68-70</sup> featured concerns. Obstetricians employed the EAV principle but with *indirect* forms of MMV, from holding similar objections over the direct method (lung rupture, infection and distaste, especially). The devices of Pierce MacKenzie,<sup>68</sup> Edward Graber,<sup>69</sup> and FA Alexander and Charles Martin,<sup>70</sup> are illustrated in their articles: they all involve the doctor breathing into apparatus applied to the newborn. Frank Rossiter,<sup>71</sup> at Pittsburgh 1942, would consider MMV only for resuscitation of the newborn, when "It has advantages and disadvantages but is still frequently used ... with very good results". The preference for mechanical inflators is evident in a 1937 *Lancet* report of use of the "E&J" resuscitator for 500 newborn in England,<sup>72</sup> though Ralph Tovell and Joseph Remlinger in the US, 1941, conceded, "In some instances mouth to mouth insufflation may be indicated" for the newborn.<sup>73</sup> Paluel Flagg's 1944 *Art of resuscitation* did not include MMV among his many described methods of inflation.<sup>74</sup>

### Outside the hospitals

A *Lancet* 1938 Annotation<sup>75</sup> endorsed advice on artificial ventilation methods for resuscitating from drowning soon after Frederick Banting et al's Toronto animal drowning experiments, which were admitted to be incomplete but were published on the basis of the urgent need for best methods.<sup>76</sup> They recommended airway clearance, immediacy of artificial ventilation, not by MMV but by the Schäfer method, and tracheal insufflation at about 3 L/min of 80% O<sub>2</sub> with an (amazing) 20% CO<sub>2</sub>. The investigators stated they had found supplying these gases "effective", without supplying any actual data, other than indicating that measured O<sub>2</sub> and CO<sub>2</sub> levels were both far too low in a victim with their classification of Type 1 drowning (one with "spasmodic convulsions"). Nor next year, for electrocution, did HF Collier, University of Birmingham, UK,<sup>77</sup> advise any mode other than NPV, for example by Frank Eve's "old teeter-board method".<sup>22[pp.66-7]</sup> For cardiac resuscitation, a *Lancet* 1943 Annotation<sup>78</sup> wanted pulmonary ventilation established by a mechanical resuscitator, or by bag or manual inflation; and by 1949, for respiratory arrest, *The Lancet* stated<sup>79</sup> (in quoting the EAV versus NPV experiments of Macintosh and Mushin,<sup>80</sup> see below): "in an emergency

*it does not matter which method [ranging from Silvester's to direct lung inflation methods] is used, so long as some air gets in and out of the alveoli".*

In the world outside the consulting rooms of physicians, where drowning, suffocation, hanging and poisoning took place, doctors were little involved in first aid resuscitation. When offered, it usually came from lay people: passers-by, then lifeguards, firemen and police, while in the US, according to *The Lancet*,<sup>79</sup> "laymen, such as the police or the fire force" could also be called into hospitals.

Following Heinrich Dräger of Lubeck's first positive pressure resuscitator, the Pulmotor of 1908, various inhalators were developed in the US, well described in Flagg's *The Art of resuscitation*.<sup>74</sup> These were devised to inflate or insufflate the lungs by IPPV delivered through a face-mask with oxygen or oxygen mixtures. Few of these could be immediately available on-site or as simple to administer as direct MMV.

In Canada, mouth-to-mouth insufflation was rated in 1942 as a very valuable method for infants and children — in preference to mouth-to-nose, which was seen as much more suitable for adults. Use of a cloth "filter" was advised for MMV.<sup>81</sup> Two years later in Australia, it was considered "All the older methods of artificial respiration should be abandoned and, if no special apparatus is at hand, direct mouth-to-mouth insufflation should be used".<sup>82</sup> But Cecil Drinker's 1945 viewpoint was that "at the present time, however, except for use on stillborn infants, mouth to mouth insufflation has little vogue", although "In my opinion, [MMV] will always be one of the best" methods.<sup>34</sup>

NPV methods still held strong favour in the first half of the 20th century. Thus, in 1939, for apnoea after electrocution, it was Sir Edward Sharpey-Shafer's method (as he was then) that was to be applied until Eve's rocking stretcher could arrive.<sup>77</sup> And yet another "new" NPV method was still being claimed in 1945,<sup>83</sup> while in the UK even into the late 1940s it appears MMV was not being recommended.<sup>79</sup>

### Measures used by trained rescuers ("paramedics"?), early 1940s

After 14 years' investigation of methods of mechanical and manual artificial ventilation, Bernard Ross surveyed — for the American Medical Association's (AMA) Council on Physical Medicine — the methods of artificial respiration used in practical situations by the trained life-saving crews of the US Coast Guard Service and the Chicago, Detroit and Los Angeles fire departments, 1940–1944.<sup>84</sup> These lay rescuers at beaches and large commercial organisations "administer the treatment and observe the results in the overwhelming majority of cases" before medical help arrived (which happened "in virtually all cases") to provide

**Figure 3. Waters' simple method of artificial respiration**



Ralph Waters' simple line drawing of 1943 of one "simple method for performing artificial respiration". (With thanks to the American Medical Association. Reprinted from Figure 5, JAMA 1943; 123: 559-61.)

us now with a guide, even if incomplete, to the methods of treatment. The need for immediate intervention was well appreciated. Ross found insufficient data for the actual method of resuscitation to be the significant variable, except for cases of immersion; and further, regretted a shortfall in autopsy reports and that certain "features of this survey ... weaken it considerably".

Although it had been written at this time that "mouth to mouth insufflation has many adherents",<sup>73</sup> the infrequent use of MMV is indicated in Ross's data about the condition of victims at the start of treatment. In summary:

- Of the 1633 patients who were apnoeic *at the start of treatment*, 13.9% survived. MMV alone was used on only seven victims without initial evidence of spontaneous breathing; all survived.
- Of the 1679 victims for whom breathing had not stopped completely, 97.7% survived, with an inhalator used for 95.2% of these, on two occasions with survival after initial MMV.
- Initial MMV, later followed by an inhalator, was used for five patients who showed no evidence of spontaneous breathing *before treatment started*; none survived.
- Initial MMV, later followed by treatment with an inhalator, was used for five patients without definite evidence of spontaneous breathing at 30 minutes before treatment started; none survived.

## Anaesthetists pioneering MMV

### Ralph Waters

By the 1940s, anaesthetists in the operating theatre were generally well aware of rhythmic compression of an anaesthetic bag for IPPV of patients they had rendered apnoeic, using the techniques of Joseph Gale and Ralph Waters (1932),<sup>85</sup> and Arthur Guedel and David Treweek (1934).<sup>86</sup> Waters and James Bennett, musing in 1936 over "How could that which enlivens a blue newborn revive an adult?", thereby indicated that use of MMV was not unknown and might be practised.<sup>87</sup> From their experiments, they rated a correctly applied Silvester technique as the best of the manual NPV methods (but with data from only four test patients). They saw it standing "*second only to direct mouth to mouth or mouth to nose inflation as an efficient means of causing respiratory exchange without the aid of apparatus*" (which for them comprised a system of face-mask, breathing bag and valve, and oxygen connection). After 7 years, Waters<sup>88</sup> produced his lucid report on *Simple methods for performing artificial respiration* for the AMA Council on Physical Medicine around 1943; he emphasised that valuable time, even 30 seconds, must not be lost waiting for apparatus to arrive, when "*Direct inflation of the lungs is always at hand. Either the nose or the mouth may be blown into while one hand of the rescuer holds the other portal closed*". His caption for the line diagram of this method (Figure 3) included "*A handkerchief or other light material prevents contamination*".

Waters taught resuscitation to his 1941 Fellow, Robert Dripps, who taught David Cooper; he also influenced Cecil Drinker.

### Robert Dripps

In David Cooper's engaging account of his own role in the 1950s revival of MMV,<sup>89</sup> he tells us that in the 1940s "*anaesthetists, to make their lectures on resuscitation complete, always mentioned that mouth-to-mouth insufflation could be tried*". (But he soon refers — perhaps in exaggerated terms — to direct MMV as being "*aesthetically repulsive*".<sup>89[p.490]</sup>) Cooper had heard his former teacher, Professor Robert Dripps, lecturing on MMV to students: "*In passing it was mentioned [by Dripps] that if you could do nothing else, try blowing air into the patient's mouth while closing the nose with your fingers*".<sup>89[p.494]</sup> So I do find it curious that when Dripps was second author after Julius Comroe Jr in their 1946 article on artificial respiration,<sup>90</sup> there is no mention of MMV. On that occasion, it was the Schäfer method that they extolled as the most efficient temporary emergency method until a properly skilled resuscitator — at best, an anaesthetist — could take over,

using the most efficient methods. Perhaps Dripps was not so sure then? (or outvoted!).

### Robert Macintosh and William Mushin

In a 1946 Oxford (UK) study on two subjects, one of whom was Professor Edgar A Pask, renowned at offering himself for high-risk wartime experiments, Macintosh and Mushin produced apnoea by deep ether anaesthesia.<sup>80</sup> They then demonstrated with a spirometer that lung inflation by mouth or by Oxford inflator, through an endotracheal tube into the subject, was superior to the NPV methods they tested. Mouth-to-tube EAV was better than the best of five different versions of Eve's method by 55%, than Silvester's method — which they ranked the next useful mode of NPV — by 190%, and than the lowest-ranked method, Schäfer's, by 125%. They thereby anticipated the 1952 experiments of Elam et al<sup>36</sup> (see below).

### James Elam

Despite occasional reports, *non*-neonatal usage of MMV was so limited at that time — especially as Ross's 5 year survey of 1944 indicated EAV was “infrequently used by rescue personnel”<sup>84</sup> — that Elam, the next anaesthetist significant in the revival of MMV, could feel justified in labelling his 1946 emergency use for non-breathing polio patients as a “rediscovery” of the method.<sup>91</sup> He later reminisced “*During the polio epidemic in Minnesota in 1946, I did mouth-to-mouth breathing as an instinctive reflex many times on patients with combined spinal-bulbar paralysis at times of equipment failure. ... There were no Danes to point out the virtues of IPPV with oxygen via tracheal tube, bag, and anesthesia nurse. ... on one night I was stuck with this chore for 3 hours .... The method was natural improvisation on the spot.*”<sup>91</sup> (Elam, like 1500 students at Copenhagen 7 years later, was selflessly placing himself at risk, as there were no polio vaccines then.)

Elam recalled how, 4 years later as an anaesthetic resident, he used mouth-to-tube breathing for the safe transfer of curarised patients from induction room to the operating theatre<sup>91</sup> (as other anaesthetists might also have improvised; Peter Safar describes himself doing the same as an anaesthesia resident, 1950–52<sup>92</sup>[p.266]). Elam later referred to his “rediscovery” of MMV,<sup>91</sup> but that descriptive word could more properly be *renewal* or *revival*.

In a 1949 comprehensive review (223 total references) of resuscitation for cardiorespiratory arrest (Part 2 covers asphyxia neonatorum), anaesthetists **Sydney Wiggin**, **Peter Saunders** and **George Small**<sup>93</sup> cite Waters<sup>88</sup> (above) for fundamental principles. They used MMV or manual artificial respiration in the absence of an anaesthetic machine, or Keiselman's resuscitator or a simple mask-rebreathing bag-oxygen system.<sup>93</sup>[pp.374-5] “Manual methods

of artificial respiration are difficult and unsatisfactory”. For the apnoeic newborn, they advanced arguments of safety for preferring Keiselman's resuscitator. If it is unavailable “mouth to mouth insufflation is considered the next choice”.<sup>93</sup>[p.415]

**The priority rights for reviving MMV seem better regarded as a shared honour, so that aspect will now be looked at more closely.**

### The resurgence of MMV, a US achievement

Julius Comroe Jr<sup>94</sup> charted the pathway to lay acceptance of MMV: it took “*eight years of work between 1950 and 1958, mostly supported by the armed forces, mostly done by groups at one time or another associated with the Medical Research Laboratories of the Army Chemical Center at Edgewood, Maryland, and mostly orchestrated by its civilian director, [David] Bruce Dill. The sequence of events began as gas mask-to-gas mask resuscitation, continued as mouth-to-face mask resuscitation, and ended as the mouth-to-mouth method*” (my emphasis). A historical perspective was later provided by Dill in 1980.<sup>95</sup>

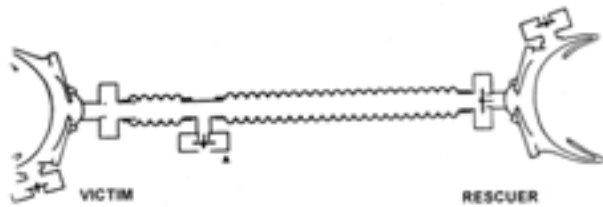
### The Cold War and the revival of MMV

The “Cold War” that started soon after the end of World War II accelerated the US Army's development of methods against a possible enemy attack with paralyzing (anti-cholinesterase) nerve gases, these having been developed in Germany before the War ended.<sup>95</sup> The Chemical Corps Medical Laboratories of the Army Chemical Center in Maryland, where research was performed on respiratory problems associated with nerve gas poisoning, “became instrumental in the reintroduction of the mouth-to-mouth technique” of EAV.<sup>89</sup>[p.498]

At a 1948 US National Research Conference on Resuscitation, Dill reported that “*Motley suggested the need to consider the mouth-to-mouth method of insufflation [to replace the unsatisfactory Schäfer NPV method] and then Behnke proposed a face mask with a tube for mouth-to-mouth insufflation*”, but their ideas were not taken up.<sup>94</sup>[p.1028] Julius Comroe offered explanations as to why, beyond the usual ones of O<sub>2</sub>/CO<sub>2</sub> changes, lung damage and rescuers' exhaustion: people's fear of infection, such as polio and tuberculosis; and the armed forces' opinion of MMV as of little use in an atmosphere contaminated with nerve gases.<sup>94</sup> The National Research Council did consider EAV, but Cecil Drinker advised that it too soon became fatiguing, and Dripps doubted that people would use it on a stranger.<sup>91</sup>[p.264]

**David Cooper** was assigned to Edgewood, but it is difficult to fix dates precisely as he related his transfer there

**Figure 4. The Cooper and Johns (C & J) resuscitator**



Original arrangement of mask-to-mask resuscitator (C and J resuscitator). Resuscitator is connected to the exhalation valve of victim's gas mask after removal of valve leaflet, and to rescuer's exhalation valve which is left intact. To ventilate victim, rescuer inhales through his mask, covers the T-outlet valve (A) with his hand, and exhales. Hand is removed from valve A to allow victim's exhaled air to escape.

*"The original arrangement of mask-to-mask resuscitator (C & J Resuscitator)" was an early solution proposed for apnoea during nerve gas warfare, which stimulated James Elam to definitive studies of expired air ventilation. (Reprinted from Cooper DY. Minireview. Mouth-to-mouth resuscitation: influence of alcohol on revival of an old technique. Life Sciences 1975; 16: 495, Figure 1, with permission from Elsevier.)* ♦

to the Korean War starting in "June 1949", whereas it was June 1950. He then told us in his account<sup>89</sup> how, one evening at Edgewood over a few beers with Richard Johns, the two were deploring the Army's plans for using inadequate methods of artificial ventilation for coping with a possible nerve-gas threat. With Cooper remembering Dripps' lectures and inspired by diagrams in Drinker's monograph<sup>34</sup> on pulmonary oedema ("1947" edition,<sup>89</sup> originally a 1945 issue), they devised a system to provide modified MMV. Within a day, they had constructed a surrogate MMV apparatus (to be named the Cooper and Johns [C & J] resuscitator; Footnote 6), enabling mask-to-mask EAV (Figure 4).

Around 1952, Elam joined John Clement's research laboratories at the Army Chemical Corps in Edgewood.<sup>94[p.1029]</sup> Cooper has recorded<sup>89[p.496]</sup> that, "a year later" (than 1950?), he was advised that James Elam, Elwin Brown and John Clements "had jumped on the resuscitator, found it highly effective, designed mouth to mouth resuscitators for civilian hospital use, and were working to get this method accepted as a general method of artificial respiration to replace the manual methods". Cooper states further that, in early 1952, he saw a letter Comroe had written indicating that he "had tested the mouth-to-mouth, mouth-to-mask

**Footnote 6.** The Army eventually patented the C&J, once Cooper incorporated John H (Jack) Emerson's automatic valves<sup>89[pp.496-7]</sup> to replace the intermittent finger-stopping needed for inflation; meanwhile, the Army Chemical Corps continued with research on mask-to-mask expired air ventilation, culminating in the Denver 1957 Conference on Nerve Gas Poisoning<sup>89</sup>). ♦

and mask-to-mask systems, and found them to be effective techniques of artificial respiration".

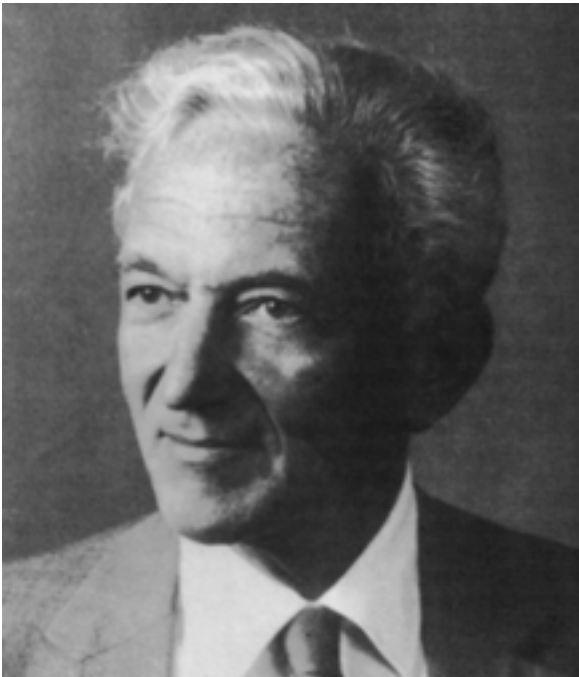
In that same year, Elam and his team conducted experiments using Elam's own 1952,<sup>94[p.1029]</sup> simpler mouth-to-mouth or mouth-to-tube methods — not the C & J resuscitator. (I find it a little surprising that, as far as I can see, the C & J is not acknowledged or even mentioned by them;<sup>36</sup> Dill's 1980 assertion<sup>95</sup> that Elam and colleagues described using it has to be mistaken.)

The 1952 studies of James Elam (Figure 5) et al<sup>94[p.1029]</sup> on EAV, published in their 1954 landmark article in the *New England Journal of Medicine*, showed validation of the use of expired air, either by mouth-to-mask or by mouth-to-tube.<sup>36</sup> They studied nine apnoeic patients (anaesthetised, intubated and receiving a suxamethonium infusion), for 23 procedures by five operators. By measured parameters, EAV was proven adequate to maintain satisfactory oxygenation and alveolar pCO<sub>2</sub> for a patient. The "results ... establish the general applicability and adequacy of the method".

**Figure 5. James Elam**



*In 1952, James Elam demonstrated that expired air ventilation could maintain adequate oxygenation and CO<sub>2</sub> excretion in anaesthetised, intubated, paralysed patients. He went on to conduct a strong campaign to have mouth-to-mouth ventilation accepted for resuscitation. (With thanks to the American Society of Anesthesiologists.)* ♦

**Figure 6. Peter Safar**

*Peter Safar validated the efficacy of expired air ventilation on anaesthetised paralysed volunteers in 1956–58, and waged an effective campaign for its worldwide acceptance. (With thanks to the American Society of Anesthesiologists.)* ◆

This major advance in treatment was still only part-way to the ultimate “pairing”<sup>94</sup> of victim and rescuer-without-equipment, but outstanding further contributions in the field of EAV from Elam are clearly set out by Comroe in his engaging pocket history of EAV,<sup>94</sup> and by Peter Safar.<sup>96</sup> Elam later recalled<sup>3[p.24],91</sup> that he “then besieged the Surgeon General and the Red Cross to recognise the method of Elisha(1<sup>8</sup>)”, but without success, then “decided there had to be more prophets”.<sup>91</sup> Enter anaesthetist Safar. The now-legendary tale of the October 1956 2-day Kansas City to Baltimore car-ride when Elam recruited Safar — at first mildly sceptical — provided a decisive new player to champion MMV at a time when “first aid agencies still jealously adhered to the teaching of back-pressure arm-lift” techniques.<sup>92[p.267],96</sup>

**Peter Safar** (Figure 6), of tremendous enthusiasm and unbounded energy, completed the initial clinical experimental confirmation of MMV on 31 professionals and then 167 brave lay volunteers by December 1956,<sup>97</sup> though studies continued into 1958, mostly on weekends. Though a newcomer to MMV, he and his colleagues soon made many contributions — which were truly immense — to its elaboration and development, to its acceptability and uptake. His series of clinical and experimental investigations

by controlled tests (all without insurance cover!<sup>92</sup>) were not on mammals, whose airways are anatomically different from those of humans, but on people, whom he saw as needing to be rendered unconscious, apnoeic and suxamethonium-paralysed but *unintubated*, for such tests to mimic the field situation (“Eighty anesthetized patients were selected at random”!<sup>98</sup>). They validated the effectiveness and practicality of “plain” MMV for regular emergency resuscitation; while its “teachability” was demonstrated in Safar’s reporting that as many as “90% of 164 untrained rescuers performed this method satisfactorily after one demonstration”.<sup>7[p.341]</sup> Safar and Captain Martin McMahon — with the suggestions of Austin Lamont and Elam — conjoined two oral airways to construct the S-tube oral airway device to bypass aesthetic objections.<sup>99</sup> After criticism that lay use of the device could prove dangerous, Safar discovered that without it, “lay persons unhesitatingly performed mouth-to-mouth breathing in the field”<sup>92[p.270]</sup> (see Footnote 7<sup>100</sup>).

The standard EAV preference became “mouth first, nose second”.<sup>92[p.270]</sup> Ultimately, MMV methods were unaccompanied by expiratory compression of the chest and/or abdomen, which had been a feature of resuscitation practice of artificial ventilation for well-nigh two centuries.

To summarise the major resuscitation contributions of Safar and his team to MMV:

- He emphasised the problem of upper airway obstruction (tongue and soft palate<sup>98</sup>) and its correction, without which MMV could not be successful. The technique he introduced was that of head-tilt/chin-lift (an Austrian method he said he saw before World War II, but US anaesthetists also used it); plus, jaw-thrust when needed — the Esmarch–Heiberg manoeuvre from the 1860s.<sup>92,98</sup>
- With Lourdes Escarraga and Elam,<sup>101</sup> he definitively established the superiority of MMV over arm-lift/chest-pressure manual methods. “Mouth first, nose second, became the standard.”<sup>92</sup>
- He incorporated the “A-B-C” components into an integrated system for cardiopulmonary resuscitation (CPR), first presented in autumn 1959 at Ocean City (Maryland);<sup>3[p.30]</sup> while the first pre-hospital, home CPR success using EAV occurred on a Mr B D in Baltimore, summer 1960.<sup>3[p.30]</sup>
- He played a major role in establishing MMV and CPR in emergency practice worldwide.<sup>100</sup>

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**Footnote 7.** *Peter Safar has written the EAV–cardiopulmonary resuscitation story many times, but perhaps the best elaboration was to the Wolf Creek 1975 CPR Researchers Conference<sup>92</sup> (see Figure 7). His credentials entitling eminence in this field are clearly set out in his autobiography in the Wood Library-Museum series, *Careers in anesthesiology*.<sup>100</sup>* ◆

### The rising predominance and eminence of MMV

"The triumvirate of Elam–Safar–Gordon rapidly convinced the world to switch from manual to mouth-to-mouth methods within one year".<sup>92[p.271]</sup> They were helped by wide newspaper coverage with reports of successes and technique. From the scientific investigations presented at the 1957 Symposium on Mouth-to-Mouth Resuscitation (Expired Air Inflation) and reported to the AMA Council on Medical Physics,<sup>7</sup> all multicentre studies were in agreement on rejecting manual NPV. Thus, Archer Gordon et al "indicated the unequivocal superiority of mouth-to-mouth resuscitation over all manual methods in all age groups".<sup>7[p.327]</sup> Dill's introduction to the symposium report has a roll-call of renowned pioneering names, including those at the Edgewood Medical Laboratories.<sup>7[p.1]</sup> Supporting bodies were the US National Academy of Sciences–National Research Council and the American National Red Cross. Pioneering resuscitation experts are shown in Figure 7.

### The acceptance of MMV

The sequence in the acceptance of MMV included:

1. In 1957, after multiple demonstrations of the superiority of this technique over manual methods of artificial ventilation, the United States military, on receiving Dill's advice of Safar's methods,<sup>3[p.27]</sup> adopted the EAV resuscitative method to revive unresponsive victims.
2. The US National Research Council<sup>3[p.27]</sup> recommended MMV as the official ventilatory mode for basic CPR for children on 8 March 1957,<sup>92[p.271]</sup> and for adults in November 1958.
3. The medical profession was informed of the method through the American Society of Anesthesiologists meeting at Los Angeles in autumn 1957, and then the AMA meeting in June 1958.
4. Safar's presentation to the annual conference of Scandinavian anaesthetists at Gausdal, Norway, in September 1958 saw the first international acceptance of EAV; to be followed, 1959–60, by the creation of Åsmund Lærdal's working models for teaching (mannikins). These "Resusc-Annes" helped to overcome the difficulties experienced in trying to mass teach MMV on conscious volunteers.<sup>100[pp.146-7],102</sup>
5. Safar took A-B-C resuscitation including EAV around the world on lecture tours: in spring 1959 to India and Indo-China; then in spring 1960 to the World Congress on First Aid in Sydney (which also included William Kouwenhoven's new work on external cardiac massage for CPR). His influence led to Australian surf-lifesavers immediately switching to MMV.<sup>100[p.144]</sup>
6. In 1962, the Basic Life Support of A-B-C was recommended for CPR at the International Symposium on

Figure 7. Wolf Creek Conference, 1975



**Front:** James Jude, David Leighninger, Louis Del Guercio, Guy Knickerbocker, Charles Guildner, Don Dembo;  
**Middle:** Christopher Rattenborg, Robert Huber, Peter Safar, Robert Oswald, Joseph Redding, Hugh Stephenson, Jr., Archer Gordon, Leon Resnekov, Gerald Modell, Leonard Scherlis, James Elam, James Evans;  
**Back:** Keith Thwaites, Paul Zoll, Edwin Nemoto, Larry Birch, Eugene Nagel, Asmund Laerdal.

*Eminent participants at the Wolf Creek Conference on Cardiopulmonary Resuscitation, 1975. (Reprinted from Safar P, Elam JO, editors. Advances in cardiopulmonary resuscitation, 1977: frontispiece, with kind permission of Springer Science and Business Media.)* ◆

Emergency Resuscitation at Stavanger, Norway. The 10 recommendations<sup>103</sup> included that:

- First-aid workers, school children and the public were to be taught EAV per the mouth or nose.
  - Airways and other adjuncts were to be restricted to professionals.
  - "The best way of disseminating the knowledge of EAV would be its compulsory teaching to schoolchildren" (endorsed by the World Health Organization, in Stockholm, 1963).
  - Artificial ventilation should accompany external cardiac massage, which latter (it was considered at that time) should be limited to professionals.
7. The work establishing MMV's acceptability in the US was taken up in other countries. For instance, by Henning Poulsen and his colleagues in Denmark and Ivor Lund in Norway, then later in Britain (see below).
  8. In 1963, after Kouwenhoven's introduction of external cardiac massage, cardiologist Leonard Scherlis started the American Heart Association's CPR Committee, whose CPR program for physicians endorsed EAV the same year, when adopting Basic Life Support for CPR, becoming the forerunner of CPR training for the general public.

## In Britain

The take-up of MMV was slower in Britain than in the US or Scandinavia. In 1958, *The Lancet's* Annotation opinion<sup>104</sup> was that for emergency resuscitation, it was better to use the "Holger–Nielsen [sic] method of manual artificial respiration ... easy to learn and effectively ventilates", rather than wait for equipment — with no mention of MMV. Even by 1960, J Cox et al could write with their Royal Navy studies<sup>59</sup> that "practical experience of it [MMV] in Britain was sparse". From 22 anaesthetised paralysed subjects studied, they concluded that mouth-to-oral (double-) airway was the EAV method of choice because of the aesthetic objections to MMV, which a *Lancet* editorial upheld.<sup>105</sup> For the same reasons, mouth-to-nose, not mouth-to-mouth, was preferred for direct EAV. However, a month later the journal printed Eric K Gardner's counter-arguments dismissing seven common criticisms of EAV.<sup>106</sup> And within 2 years, Cox's co-author Ronald Woolmer, representing Great Britain, was a signatory to the Stavanger recommendations.<sup>103</sup>

## Some attitudes of hesitation or even reluctance

An outline of the universal acceptance and great benefits of MMV, but also the changes in attitude to it, and increasing reluctance to undertaking it, which developed in the 1980s, would require a further article. However, there were fore-warnings. In 1954, Dripps<sup>91</sup>[p.264] considered it unlikely to be acceptable to the public, and Captain Marty McMahon, Baltimore Fire Chief, reported his ambulance personnel's initial reluctance to "kiss a bearded, vomiting bum".<sup>92</sup>[p.270] Safar surmised that, though acceptable to use for infants, it was rarely so with adults — "probably because of the hesitancy of many people to 'kiss' a moribund stranger",<sup>7</sup>[p.338] with MMV being the butt of "public objection to kissing strangers".<sup>3</sup>[p.26] James Whittenberger<sup>36</sup> saw reluctance at "direct contact with the lips of the moribund person"; while Peter Karpovich, in 1953, had already put it more luridly, even before the return of MMV (see Footnote 8).<sup>22</sup>[pp.9,10]

For myself, the group that has always seemed at the forefront of selfless commitment to MMV has been the nursing profession.

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**Footnote 8.** In *Adventures in artificial respiration*, Peter Karpovich wrote: "If the victim happened to be a movie starlet looking exactly the way she looks in technicolour, there probably would be a stampede among eager male rescuers anxious to be of help. But if the victim were an old, dirty, bearded, drunken man, decorated with three Wassermann crosses, lying in a gutter with his respiration stopped because of alcoholic poisoning, how many male or female lifesavers would be eager to touch with their lips the mustache and beard covered with vomitus? A real Samaritan might do it, but how many real Samaritans are there among us?"<sup>22</sup>[pp.9-10] ◆

## In conclusion

Thus, the decade of the 1960s started with MMV being accepted into practice as the endorsed method of artificial ventilation for basic CPR. It achieved widespread acceptance throughout the rest of the 20th century. However, objections to its use and reluctance to employ it, both lay and professional, were later to become more pronounced with the 1980s, for reasons which included fear of infectious agents, such as the key viruses of hepatitis C, influenza, herpes simplex and then HIV/AIDS.

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