

Never quite there: a tale of resuscitation medicine

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Resuscitation medicine is of its nature multidisciplinary and for that reason something of an orphan. Perhaps that is why its development as an effective branch of medicine was so long delayed, for it started a little over 40 years ago, within my own professional lifetime and very much within my memory.

Amongst the precepts that drive progress in science and in medicine are four that are manifestly true yet call for vigilance and wisdom if a correct balance is to be maintained between them: first, the willingness to accept new ideas that are supported by good evidence, and to discard quickly those that have none; secondly, the defence of practices that are demonstrably successful, and their rejection only for others that are truly better; thirdly, the acceptance that heterodox views are not necessarily wrong, and an appreciation that valid ones are often particularly important; fourthly, an awareness that fashion may be a more potent force than science.

Many current practices that we regard as relatively new were first introduced long ago. Often they came close to acceptance – some indeed had a brief vogue – only to be abandoned or forgotten by our forebears. They were not quite there. Even now, however, good scientific evidence is either being ignored or is accepted into clinical practice far too slowly. We too do not learn – and we are still not quite there.

Artificial ventilation

Biblical references apart, the sixteenth century anatomist, Andreas Vesalius,¹ must be considered the true father both of modern anatomy and of resuscitation. In 1543, at the age of 28 he published *De humani corporis fabrica*² and described in it how the lungs of animals collapsed after the chest was opened and that the heart was then affected. But he also wrote

that life may... be restored to the animal, an opening must be attempted in the ... trachea, into which a tube of reed or cane should be put; you will then blow into this, so that the lungs may rise again and the animal take in air ... I have seen none ... that has afforded me greater joy!

Sadly, his heterodox views were widely condemned. To avoid execution, allegedly for conducting an autopsy on a nobleman whose heart was seen to be beating, he set out on a pilgrimage to the Holy Land but died before he was able to return.

In 1732, Tossach used mouth-to-mouth ventilation effectively to resuscitate a miner in Scotland who had been declared dead after a fire.³ He found 'not the least pulse in either heart or arteries, and not the least breathing could be observed'. He also wrote:

he was to all appearance dead. I applied my mouth close to his, and blowed my breath as strong as I could, but having neglected to stop his nostrils, all the air came out of them; wherefore, taking hold of them ... blew again my breath as strong as I could, raising his chest fully with it, and immediately I felt six or seven very quick beats of the heart ... the pulse was felt soon after.

Tossach added that after about an hour the rescued man began to yawn and to move. He walked home four hours later, one imagines somewhat unsteadily!

When John Fothergill, a London practitioner, learned about the incident in 1745, he declared in relation to this discovery that for facts of such great importance it is the duty of everyone 'to render them as extensively public as it is possible'.⁴ And so indeed he did, with a list of indications for its use that included suffocation in water. Drowning was by then a matter of great and growing concern. Fothergill was influential in the formation in 1767 of a Society for the Recovery of Drowned Persons in Amsterdam, later called the Humane Society. Mouth-to-mouth artificial ventilation was recommended with other treatments of more doubtful efficacy, including insufflation of tobacco smoke into the rectum.

Other humane societies followed, including the Royal Humane Society of London in 1774, but here mouth-to-mouth ventilation was viewed less enthusiastically.

Occasional recommendations for mouth-to-mouth ventilation continued through the nineteenth and early twentieth centuries,⁵ but it was well out of fashion and virtually forgotten. William Hunter considered it to be 'a method practised by the vulgar',⁶ and even Herholdt and Rafn considered in their



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famous 1796 treatise that it was ‘a very toilsome and loathsome act’ and of only little use.⁷

So it was that the Royal Humane Society in 1782, less than 20 years after it had been formed, recommended bellows once again in preference to mouth-to-mouth ventilation.⁸ But using bellows to blow into the nose was clearly not satisfactory, nor universally accepted. The Vesalius technique of tracheal intubation became briefly fashionable again, even while bellows and the mouth-to-mouth methods were still in use. But by 1855 the recommendations of the Royal Humane Society made no mention at all of artificial ventilation.⁹

Surprisingly, electricity was also playing a role in artificial ventilation at this time. By 1872 there were records of many impressive apparent successes.¹⁰ The principal protagonist was a Frenchman called Duchenne who believed that ‘electric excitation’ of the phrenic nerves was the best solution for asphyxia.¹¹

But mouth-to-mouth ventilation, intubation, and phrenic electrotherapy were all generally considered loathsome or dangerous or too complex. Attention therefore turned to much less effective methods of artificial ventilation performed by external manipulation of the chest wall in order to increase and decrease lung volume, such as the Sylvester and Schäfer methods. Things had seemed to be going in the right direction, but we were not quite there. And it all went wrong for a long time.

Cardiac massage and chest compression

Cardiac massage and chest compression may have been used first by John Hill, a British dentist, in 1868.¹² Boehm in 1878 described successful experiments in cats.¹³ The technique of external cardiac massage using compressions over the heart was quickly applied clinically by Koenig, a surgeon in Göttingen. In a textbook of surgery in 1883,¹⁴ he mentioned that the technique had saved six patients who had been pulseless. He achieved his successes despite combining chest compressions with relatively ineffective methods of artificial ventilation.

External chest compressions survived, at least in Germany, for several more decades¹⁵ and continued to be used in association with the inefficient methods of artificial ventilation by then in

Key Points

History teaches us that prejudice against new ideas can lead to long delays in the introduction of useful treatments

Heterodox views, old or recent, are not necessarily wrong and often deserve closer scrutiny than is generally accorded them

Although the essential components of successful resuscitation were all discovered before 1900, they were not integrated until a little over 40 years ago: it could all have been much sooner

The development of resuscitation medicine has been hindered by its multidisciplinary nature: it has been owned by no one specialty

vogue. Why, then, did we forget? Perhaps if mouth-to-mouth ventilation had also persisted, then success would have been compelling and resuscitation would have been commonplace nearly 100 years earlier than it actually was. We were not quite there...

Open cardiac massage might have seemed a more obvious strategy for re-starting the heart, but only in 1874 was its experimental use described by Moritz Schiff.¹⁶ Leaving aside the experience of Vesalius who opened the chest of a man whose heart was seen to be beating, the first recorded attempt at direct chest massage in man was by Niehans in Berne – recorded by a colleague in 1903.¹⁷ The first definite success occurred in Tromsø a little over a hundred years ago but it was described only after Igelsrud told a colleague of it when he visited the USA.¹⁸

Interest continued for a while. Green in 1906 reviewed heart massage as a means of restoring the heart beat.¹⁹ He described 40 cases that were by then in the literature, of which nine had been ‘entirely successful’ and eight others had transient recovery of pulse and respiration. But we did not learn. We were not quite there. For many years, attempts at cardiac massage were made only infrequently. Few were even interested in resuscitation.

Electrical pacing

Electrical pacing of the heart also has a longer history than most appreciate. Its origin is doubtful because there are several accounts of resuscitation by electricity in which mechanisms of recovery are at best speculative. Here is one from Herholdt and Rafn in 1796:

An electric shock applied across the chest from the right side to the left side, directly over the large blood vessels of the heart and lungs – such a shock of suitable strength, applied when the lungs are filled with pure atmosphere of vital air, is the best cardiacum in a drowned person.⁷

Aldini, Galvani’s nephew, recommended the use of ‘galvanic power externally to the diaphragm and to the region of the heart’ for drowned persons, but only after the lungs had been inflated – sound enough advice.²⁰ Although he claimed that shocks administered in this way ‘cannot fail’, we have no idea how often these and other nineteenth century suggestions for electrical stimulation were indeed successful.

Drowning was the stimulus for developments in resuscitation in earlier centuries, but by the nineteenth century it was the deaths under chloroform and ether anaesthesia that were all too common and equally tragic. The variety of animals used experimentally by Steiner in 1871 is, however, surprising:²¹ he successfully paced the chloroform-arrested hearts of one donkey, six rabbits, 10 dogs and 14 cats, using direct current pulses applied to a needle thrust into the heart via the chest. But he was unsuccessful in the one human patient.

Soon afterwards, however, it did work in man. Green treated seven patients with chloroform asystole by the intermittent application of a galvanic current from hand-held electrodes placed over the lower ribs and the neck on the left side.²² The cases are described graphically – especially the five who recovered, one of whom was an elderly man:

A small quantity of chloroform had been given when the pulse suddenly stopped and the man appeared dead. The Galvanic apparatus was near and was instantly used. A deep and rapid inspiration, succeeded by a strong noisy expiration like a loud groan, was the immediate result, and at the same time he started up into the sitting position. The circulation was at once restored and he entirely recovered.

The great McWilliam, who did much to uncover the secrets of fibrillation, also carefully studied closed chest pacing.²³ He recommended large electrodes with saline to enhance conduction, and emphasised the need for simultaneous artificial respiration. He urged that this should become a routine emergency procedure, yet mysteriously it was forgotten.

The rediscovery of pacing is usually ascribed to an American, Albert Hyman, whose classic paper was published in 1932.²⁴ His interest had started when he believed that he had restarted a heart by a direct needle prick. What, then, was more obvious than to enhance the efficacy of the stimulus by applying electricity through a needle that had been passed through the chest and into an arrested heart. Hyman does seem to have been the first to use the term 'artificial pacemaker'. He also pioneered a bipolar electrode. But there were problems reproducing his successes, and he was declared to be a 'clumsy fraud' by the Siemens company that had been interested in his devices. His position would have been stronger if he had kept clinical records, especially of the two patients for whom he claimed good results.

If Hyman was careless in his record keeping, he was nevertheless generous in crediting an Australian called Gould for having reported in 1929 the successful resuscitation of a child using a technique similar to his own. Gould could never be traced, but a recent determined attempt to solve the mystery²⁵ led to the realisation that Mark Lidwell of Melbourne was the real name of the pioneer who had presented his ideas and experience at the Congress – which involved ventricular rather than atrial stimulation as advocated by Hyman. Perhaps he might now share the credit for bringing clinical pacing into the twentieth century.

We still had to wait until 1952 for external pacing to be accepted²⁶ – though the first commercial units were produced in 1950 to the design of Bigelow, Callaghan, and Hopps^{27,28} – and until early 1959 for intracardiac pacing.²⁹ We were almost there 80 years earlier, so why did we forget?

Defibrillation

Abildgaard, a remarkable Danish veterinarian and man of many talents, is well known in his native Denmark and has more than one statue in his honour, but he deserves wider acclaim. An excellent account of his role in defibrillation and a translation from Latin of his relevant writings were published to commemorate the bicentennial of his experiments.³⁰ He used cocks and hens only because his assembly of 10 Leiden jars did not provide a sufficient capacity discharge to kill a horse. So it was:

I took a hen, which I knocked down with the first shock directed to the head ... it lay without feeling as if completely dead and was unable to be aroused by any stimulus ... I tried an electric shock directed through the chest to the spine ... it rose up and, set loose on the ground, walked

about quietly on its feet ... after the experiment was repeated rather often, the hen was completely stunned, walked with some difficulty, and did not eat for a day and night; then later it was very well and even laid an egg.

Credit for the discovery of defibrillation is usually given to much later work. Prevost and Batelli worked in Geneva on high strength electric currents on dog hearts to show that they could stop any effective heartbeat and also restore it. Their scientific interest in the restoration of the heartbeat is clear from several papers.³¹

In the dog one can if a high voltage current is applied in time stop the tremulation [of the heart] caused by the low voltage current. A dog which had been lost due to paralysis of the heart can be saved in this way.

But it does seem that they did not understand the implications of their findings in relation to sudden death in humans. This is curious and unfortunate, because 10 years earlier McWilliam had made important observations on the pathology of ventricular fibrillation in man that he believed to be the usual mechanism of sudden death.³² Once more we were so very nearly there, but not quite... Man had to wait 48 more years. Why did we forget?

I will not comment on the seminal work of Kouwenhoven and his group,³³ or on that of Gurvich and Yuniev,³⁴ or Zoll³⁵ in relation to the development of clinical defibrillation because my purpose is to stress opportunities missed rather than notable achievements.

But Kouwenhoven's introduction of biphasic defibrillation – the use of a discharge that is in effect one cycle of alternating current – does deserve comment because it was indeed forgotten and even now is little known. This was not introduced in modern medicine for implantable defibrillators until 1989 when it had been appreciated that lower energies were required and that therefore smaller capacitors could be used.³⁶ Clinical evidence that the same held true for out-of-hospital external defibrillation followed.³⁷ But Kouwenhoven had worked with alternating current and progressively reduced the number of cycles to one – originally he called it a diphasic discharge – and regarded this as optimal. Indeed, it was used in a portable defibrillator described in 1963 that could be operated using 6- or 12-volt dry batteries.³⁸ It was many years ahead of its time and therefore ignored. Perhaps independently, our colleagues in Eastern Europe had the lower energy and probably more effective biphasic units at least 33 years before we did in the West.³⁹ So why did we take no notice or forget? We were still not quite there.

After care: advanced life support

Two therapies, hypothermia and thrombolysis, have been too long ignored by many with an interest in resuscitation.

Therapeutic hypothermia came sharply to the fore in 2002 when two studies were published in the same issue of the *New England Journal of Medicine*.^{40,41} For victims of cardiac arrest who have delayed resuscitation, the improvement in survival and in

cerebral function can be impressive. The importance of hypothermia is underscored because we have few other treatment options of any value for post-resuscitation syndromes. But therapeutic hypothermia has been well known for almost 50 years.⁴² Although it found most applications in cardiac surgery and neurosurgery, attempts were made to develop its use for resuscitation as early as the 1950s,^{43,44} and one group in particular continued to recommend this treatment strategy.⁴⁵ Yet major clinical trials have only recently been completed. Many opportunities have been lost for preserving adequate neurological function in some survivors of cardiac arrest.

Thrombolysis was used experimentally to show improved survival after cardiac arrest⁴⁶ as early as 1956 by Crowell and Smith, three years before the first clinical paper on its use for pulmonary embolus and myocardial infarction (which also went largely unheeded at the time).⁴⁷

The experiment was a striking success, with only one survivor of 15 control dogs, but 12 survivors of 14 treated with streptokinase and plasma before cardiac arrest was induced. Later observations confirmed benefits in terms of cerebral flow and cerebral function.⁴⁸ Only in recent times have observational studies suggested that more patients who have had a cardiac arrest after infarction survive if a fibrinolytic is used in subsequent management.^{49,50,51} Moreover, a pilot study of thrombolysis as a primary treatment for refractory cardiac arrest showed promising results.⁵² Yet even now thrombolysis is usually regarded as contraindicated after prolonged cardiopulmonary resuscitation. The opposite may well be found in the future: a large randomised multicentre study is likely to start in late 2003. It could have been so much earlier. We were nearly there.

Questions from the past, implications for the future

The modern era of resuscitation is regarded – appropriately – as having started in the years 1947 to 1960. But might the first human internal defibrillation have been shortly after 1899,³¹ not 1947?⁵³ Might the first human external pacing have been in 1872,²² not 1952?²⁶ Would it have been possible for mouth-to-mouth ventilation to have become established in the eighteenth century^{3,4} so that it did not have to be re-introduced in 1958?⁵⁴ And might closed chest cardiac massage have been accepted in the 1880s¹⁴ instead of in 1960?⁵⁵ We could have had biphasic defibrillation from 1963.³⁸ We could have – maybe should have – investigated properly in the 1960s both therapeutic hypothermia and thrombolysis for resuscitation.

We must not be complacent now. Over the past 25 years the success rate of out-of-hospital resuscitation has improved little. This is because we are ‘never quite there’ in another sense: not there with a defibrillator for immediate use when an individual collapses in ventricular fibrillation. The importance of time in relation to success has recently been highlighted in a re-presentation of data from a Seattle cardiac rehabilitation programme:⁵⁶ whereas the survival rate is almost 100% if patients with ventricular fibrillation are treated at once, the success rate falls to 15–40% by 4 to 5 minutes, and to 5–10% by 8 to 15 minutes.

Most cases of cardiac arrest can never be reached within five minutes even by the best emergency system. This might seem an insuperable barrier to any major improvement in the outlook from sudden premature death. But defibrillation could probably be more successful than current data would suggest. I predict with some confidence that 10 years from now the time-window for successful resuscitation will have widened and clues suggesting how this might have been achieved earlier will be recognised as having been in the public domain for many years.

There are lessons to be learned from the history of resuscitation. Progress in all disciplines can be hastened if new ideas are welcomed but then evaluated critically; if old practices are not discarded until they can be replaced by others that are demonstrably better; if we have more enthusiasm for why we should change our practices than for why we should not; and if we recognise that dogma must never be above scrutiny. So often our predecessors ‘did not learn’ when it seems in retrospect that they should have done, and so often they were ‘never quite there’ for developments that then had to wait many years. We share the same frailties and are no doubt guilty of the same sorts of errors. History will be our judge too.

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