

## ■ SPECIAL ARTICLE

Anesthesiology

1998; 89:771-6

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Lippincott Williams & Wilkins

# Cardiac Massage

## A Method Rescued from Oblivion

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DURING cardiopulmonary resuscitation, restoration of spontaneous circulation requires several basic and advanced life-support measures, including airway control, artificial breathing, cardiac massage, administration of drugs (such as epinephrine), and defibrillation, if needed. Although use of these measures in combination was introduced in the 1960s, many of the individual measures were developed only after a slow maturation process.<sup>1</sup> For instance, the closed-chest cardiac massage method described by Kouwenhoven in 1960 and still used today, as well as internal cardiac massage, were widely used at the end of the 19th century. This article provides an overview of the two different avenues of research that led to the development of internal and closed-chest cardiac massage in Europe in the last decades of the 19th century.

### Internal Cardiac Massage

The foundations for the development of internal cardiac massage were laid by Moritz Schiff.<sup>2</sup> In 1874, this German surgeon coined the term *artificial circulation* to designate the effect produced by intermittently squeezing the heart of dogs killed by chloroform inhalation: "If one opens the chest whilst slowly blowing air into the lungs (with a pair of bellows), if one rhythmically squeezes the heart with one hand, at the same time

pressing on the abdominal aorta to direct the blood toward the head, and if one takes care not to obstruct the coronary arteries with the hand, then it is sometimes possible to restore the heartbeat for as long as eleven and a half minutes after the cardiac arrest."<sup>2</sup> Nevertheless, the cardiac activity obtained by Schiff was short-lived. The same year, Hake<sup>3</sup> published similar experiments and claimed that he had invented the technique. Schiff challenged Hake, saying that Hake had seen him perform his experiments in his laboratory in Florence and had then published the results as though they were his own.<sup>2</sup>

Fifteen years elapsed before internal cardiac massage was attempted in a human. On April 13, 1887, Langenbuch, head of the Lazarus Hospital in Berlin, described the case of a patient who went into cardiac arrest while receiving chloroform anesthesia. After 30 min of artificial ventilation using the chest pressure-arm lift method described by Silvester,<sup>4</sup> Langenbuch opened the chest and "manually squeezed the heart at regular intervals." The patient died a few minutes later. However, during the massage the patient's face recovered some of its color, and, based on this observation, Langenbuch recommended internal cardiac massage as a method to treat cardiac arrest.<sup>5</sup> He received little attention outside of Germany.

On November 2, 1898, at a session of the French Academy of Sciences, Tuffier, who was then a surgeon at the Salpêtrière Hospital in Paris, reported the case of a patient treated by internal cardiac massage. Tuffier was familiar with the theory underlying the internal cardiac massage technique and had investigated this method with variable success in dogs killed by exposure to chloroform. He had never used internal cardiac massage in humans and was unaware of the patient treated by Langenbuch. He had been called to see a young man who had recently been operated on for a perforated appendix. When he arrived at the bedside, Tuffier found that the patient's heart was not beating. He started artificial ventilation as described by Silvester, at the same

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Received from the Department of Anesthesiology and Intensive Care, Hospital Bichat-Claude Bernard, Paris, France. Submitted for publication October 27, 1997. Accepted for publication April 20, 1998. Presented in part at the 1996 Annual Meeting of the American Society of Anesthesiologists, New Orleans, Louisiana, October 22, 1996.

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Key words: Cardiopulmonary resuscitation; history of medicine; 19th century.



time pulling on the patient's tongue intermittently, to no avail. Then he performed what he thought was the first attempt at internal cardiac massage in a human:

I quickly made an incision in the left third intercostal space and using my index finger separated the pericardium. For two minutes, I carried out rhythmical compressions in the vicinity of the ventricles: at first the heart undulated irregularly, and then really contracted. The pulse reappeared, the patient inspired deeply several times, he opened his eyes wide, the pupils contracted and he turned his head as after a syncopal episode. We closed the wound with an aseptic dressing and laid the patient down in bed. After several deep inspirations, the pulse once again became weak and the frequency dropped. We restarted rhythmical contractions and for several minutes the circulation picked up, but in spite of all our efforts, it dropped again for the last time. The autopsy demonstrated a clot in the pulmonary artery with atelectasis of the left lung.<sup>6</sup>

Following Tuffier's communication, reports appeared that suggested there had been several unpublished attempts at internal cardiac massage in humans between 1882 and 1898. At the same session of the Academy of Science, Bazy stated that he had witnessed such an attempt in 1892, and Michaux noted that he had used the technique himself (cited in Lenormant<sup>7</sup>). Later it was learned that internal cardiac massage had been used unsuccessfully in a patient in Bern, Switzerland, in 1880.<sup>8</sup> Thus Tuffier was not the first to use internal cardiac massage, but he did succeed in drawing the attention of clinicians to this method.

In 1900, Prus, who was head of the Institute for General and Experimental Pathology at the Imperial and Royal University of Lemberg (Austria-Hungary), reported his results with internal cardiac massage in dogs killed by asphyxiation, electrocution, or chloroform.<sup>9</sup> Prus insufflated air into the lungs using a pair of bellows *via* a tracheotomy while he massaged the heart. He explained that "it is possible to restore life to animals killed by chloroform, even when a full hour is allowed to elapse between the cessation of heartbeat and breathing and the initiation of artificial ventilation and cardiac massage." On January 19, 1900, Prus was called to see a man who had hanged himself 1 h earlier. He noted that the heart had stopped beating, performed a thoracotomy and a tracheotomy, and began resuscitation:

I started the cardiac massage after initiating ventilation with a pair of bellows. After 15 min of massage, I saw that the atria were beginning to contract . . . These

contractions became gradually weaker when I stopped the massage and were not increased by the injection of isotonic saline in a vein of the arm. Ventilation of the lungs was not satisfactory because the tracheostomy tube and bellows were inadequate. We therefore ceased the attempts at resuscitation.

Thus this new attempt was a failure, but the patient had probably been dead for an hour anyway.

Other attempts were reported during the same period, but all failed.<sup>7,10</sup> Only the patient treated by Maag in 1902 survived for a few hours.<sup>11</sup> In all these cases, the massage was done *via* a thoracotomy incision. In 1901, Mauclaire suggested using the abdomino-transdiaphragmatic approach (laparotomy followed by incision of the diaphragm and pericardium), which was used first by Poirier, then by Mauclaire himself,<sup>12</sup> and finally by Gallet in two patients.<sup>7,10</sup> The results were similarly disappointing.

In early 1902, all attempts at replicating in humans the promising results obtained in animals had failed. Factors responsible for this frustrating state of affairs may have been a long time to initiation of resuscitation, a significant contribution of anoxia to the occurrence of the cardiac arrests, and the less-than-ideal efficacy of the ventilation techniques used simultaneously with the cardiac massage. Opponents of internal cardiac massage argued that because the technique had consistently failed, the wisest course was to focus on restoring ventilation using Silvester's maneuver and traction on the tongue. Advocates of internal cardiac massage insisted that restoration of "artificial circulation" should be the first priority. However, additional failed attempts at internal cardiac massage were reported, strengthening the position of critics of the technique. In a communication delivered at the French Surgical Congress on surgery of the heart and pericardium (1902), Terrier and Raymond suggested that internal cardiac massage should perhaps be discarded.<sup>7</sup> Gallet (of Brussels, Belgium) and Vidal (of Périgueux, France) concluded from their consistent failure to restore cardiac contractions in dogs killed with chloroform that "cardiac massage is a useless and dangerous method that should no longer be pursued." Gallet stated that in his opinion the effect of internal cardiac massage was "not, as it has been claimed, to establish artificial circulation, but rather to cause flux and reflux of the blood, which is not at all the same thing as a continuous flow; this phenomenon does not seem to have any effect in restoring life; it follows that the method is useless."<sup>7</sup> Shortly afterward, Boureau drew a similar conclusion, stating that "We doubt that truly



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serious results could ever be obtained using this method of rhythmic cardiac compression, and we believe that surgeons will soon discard it, at least under the conditions in which it has been used until now."<sup>13</sup> The future of internal cardiac massage seemed bleak.

Fortunately, at a meeting of the Society of Anaesthetists (in London), Starling reported the first successful attempt a few weeks later. A 65-yr-old man, on whom Lane had performed an appendectomy, went into cardiac arrest while he inhaled ether. Lane immediately massaged the heart and started Silvester's maneuver. Effective contractions promptly appeared. Spontaneous respiration occurred after 12 min. The patient woke up and achieved a full recovery. Lane had used the new and less traumatic abdomino-subdiaphragmatic approach and had continued Silvester's ventilation until the patient was fully conscious.<sup>14</sup>

During the following months, the wave of enthusiasm generated by Lane's success brought several new reports of patients treated by internal cardiac massage. The method failed in some instances (Keen,<sup>15</sup> Mauclaire, Drucbert, Djemil Pacha, and Le Fort<sup>7</sup>). In others it succeeded in restoring effective cardiac contractions but failed to prevent death, the most likely cause of which was aspiration.<sup>7,10</sup> A few patients survived, confirming the promise held by Lane's case (Cohen in 1903, Igelsrud in 1904, Sencert in 1905, Smith and Daglish in 1905, and Gray in 1905).<sup>10</sup> One of these successful attempts occurred as early as 1901 (by Igelsrud), although it was not published until 1904 because the surgeon was concerned that he may have started the cardiac massage too early; he believed that artificial ventilation and "faradization of the phrenic nerve" would probably have sufficed had he "waited long enough for them to take their effect before starting the cardiac massage".<sup>7</sup> This case is a telling illustration of the reluctance of many surgeons to resort to cardiac massage, which was often reserved for those patients who did not respond to more conventional measures.

These few successes produced a more relaxed climate in which to analyze the advantages of internal cardiac massage. Reviews written by Halluin<sup>16</sup> in 1904 and above all by Lenormant<sup>7</sup> in 1906, by Green<sup>17</sup> in 1906, and by Mocquot<sup>10</sup> in 1909 concluded that the method was effective and that the abdomino-subdiaphragmatic approach was to be preferred because it was "easy to perform and without danger." Emphasis was put on the need to start the massage early: "Cardiac massage is more likely to restore a lasting heartbeat if it is done early after the cardiac arrest."<sup>7</sup> Attention was also directed to the

importance of oxygenating the blood, and Mocquot suggested that either "tubing of the larynx" or tracheostomy should be performed to achieve this goal.<sup>10</sup>

## Closed-chest Cardiac Massage

The development of internal cardiac massage was the result of rigorously conducted animal studies aimed at achieving "artificial circulation."<sup>2</sup> Closed-chest cardiac massage, in contrast, was discovered almost accidentally during attempts aimed at improving the results of artificial ventilation.<sup>8</sup>

One of the oldest methods of artificial ventilation was to apply pressure manually to the chest at regular intervals. In 1858, Silvester suggested that better results could be obtained using the following technique: "The resuscitator should place himself behind the asphyxiated person and should raise the person's arms above the head, then lower them while at the same time pressing gently against the sides of the lower chest."<sup>18</sup> In 1891, Koenig (in Göttingen, Germany) suggested that this method could be improved by also applying pressure to the xyphoid.<sup>19</sup> This suggestion was based in part on work done by Boehm, who in the 1870s attempted to resuscitate cats by chest compression.<sup>20</sup> Several years earlier a surgeon working in London, John Hill, used a similar method to resuscitate successfully three patients who experienced cardiac arrest during anesthesia.<sup>21</sup> In 1887, Kraske,<sup>22</sup> who was familiar with the work done by Koenig, resuscitated a 5 yr old whose heart stopped beating because of an attack of croup. After performing a tracheotomy, Kraske used Silvester's maneuver and noted that he obtained better results when he increased the rate of compression. Kraske's experiments in dogs showed improvements in blood flow during closed-chest compression. However, Kraske believed this technique was feasible only in children because of the greater rigidity of the adult rib cage. He suggested that simultaneous compression of the abdomen and chest might be effective in adults. In 1892, Maass<sup>23</sup> further improved the technique. He used Koenig's method in two patients whose hearts stopped beating during chloroform anesthesia. The first patient, a 9 yr old undergoing surgery for a cleft palate, experienced cardiac arrest after the induction of anesthesia. Maass applied pressure to the xyphoid, as recommended by Koenig, at a rate of 30 to 40 per min. After 30 min the child was considered dead. "Nevertheless, I went to direct compression of the heart region and, in my excitement, I worked very fast and vigorously."



Thirty minutes later arterial pulsations reappeared and the child finally left the hospital alive. In the second patient, Maass observed that results were better "using the faster tempo of 120 and more compressions per minute."<sup>8</sup> Maass verified the efficacy of the compressions by palpating an artery, a fact that confirms his expectation that the method would restore effective circulation rather than simply improve the artificial ventilation. After the report by Maass, closed-chest compression gained widespread acceptance in Germany as a method capable of generating artificial circulation and as a necessary concomitant of artificial ventilation. Conversely, closed-chest cardiac massage was not popularized outside Germany. Apart from Butruille (in Lille, France), who described an unsuccessful attempt in an apparently stillborn infant (cited in Mocquot<sup>10</sup>), only Crile and Dolley<sup>24</sup> reported the use of closed-chest compression outside Germany. In his review, Mocquot wrote that the technique advocated by Crile and Dolley (closed-chest compression associated with epinephrine administration and artificial ventilation) should be used in patients with cardiac arrest unless a laparotomy incision allowing to physician to perform internal cardiac massage had already been made.<sup>10</sup> Notwithstanding this support, closed-chest cardiac massage failed to generate any substantial degree of interest among surgeons outside Germany, who preferred the internal technique. In Germany, the closed-chest technique was used until World War I and then gradually slid into oblivion. Closed-chest cardiac massage was exiled to research laboratories,<sup>1</sup> not to return to the area of clinical practice until 50 or so years later.

### From Discovery to Oblivion

How can the technique of closed-chest cardiac massage now considered a fundamental element of cardiopulmonary resuscitation have fallen into disuse? At the time, the problem of treatment for cardiac arrest arose mainly in the operating room during anesthesia. As a result, surgical considerations, such as the choice of the best approach, dominated the scientific debate. Nonsurgical solutions generated little interest. In addition, internal cardiac massage had been thought of from the outset as a means to create "artificial circulation," whereas closed-chest cardiac massage, derived from Silvester's maneuver, was viewed as a side product of efforts to improve artificial ventilation. Finally, the fact that the method originated in Germany was probably an

obstacle to its acceptance. At the time, anti-German feeling was growing in Europe under the influence of France, and the works of German scientists may have been held in low esteem. Thus closed-chest cardiac massage fell into oblivion, where it remained until 1960, leaving internal cardiac massage as the only approved means to revive the stalled heart.

Several other methods currently used to treat cardiac arrest suffered a similar fate. Administration of epinephrine or calcium chloride<sup>24</sup> and use of rubber pants (the ancestors of our G-suit) that could be "inflated (. . .) to produce reflux of the blood toward the upper part of the chest and the heart" were suggested by Crile in 1906 (cited in Mocquot<sup>10</sup>). Prevost and Batelli<sup>25</sup> advocated delivering electric shocks to the heart to obtain cessation of ventricular fibrillation. However, failure to recognize ventricular fibrillation as a common cause of sudden death, poor communication between researchers and clinicians, lack of perceptiveness of discoverers regarding the importance of their findings, and a deep reluctance on the part of renowned physicians to accept changes in classic concepts and practices kept these methods, and closed-chest cardiac massage, in limbo for several decades.<sup>26</sup>

Another and perhaps essential factor is that all these methods exhibited an extremely erratic pattern of efficacy because they were used in a nonstandardized fashion, and often alone. It is true that Crile, with unparalleled foresight, advocated combined use of insufflation of air into the trachea, intravenous epinephrine, abdominal compression, and closed-chest cardiac massage, an approach that allowed him to achieve some remarkable results.<sup>15</sup> But he received no support. No one else had enough imagination and knowledge to suggest a multi-component approach to the management of cardiopulmonary arrest that can provide the consistent efficacy that would have compelled the scientific community to accept the value of resuscitation measures.

### From Oblivion to Revival: Opportunity in the History of Medical Research

The history of science teaches that a discovery can take root only if it answers the concerns of the times. A breakthrough made too early is promptly cloaked with a veil of oblivion that is lifted only when opportunity so commands. For instance, a full decade elapsed between the discovery of penicillin and its development to answer the need for anti-infectious agents created by



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World War II. Similarly, closed-chest cardiac massage was not recognized at first. Cardiac arrest was long a problem faced almost exclusively by surgeons in the operating room at induction of anesthesia, which they gave themselves. In the 1950s, the development of anesthesiology and the introduction of new agents led to increased awareness of the high mortality rate associated with anesthesia.<sup>27</sup> Anesthesiologists therefore were expected to be able to treat the complications related to their practice. Internal cardiac massage was not within their province because it required an incision to gain access to the heart. The need for a nonsurgical method of cardiac massage had arisen. In addition, intensive care was a nascent specialty at the time that was developing at a rapid pace to provide better care to victims of poliomyelitis. These patients needed to be treated by nonsurgeons and outside the operating room. Furthermore, it is at this point that the time to initiation of cardiac massage was emphasized as a key factor in the success of resuscitation. Although results in terms of neurologic recovery were fairly satisfactory, the time needed to perform thoracotomy caused a heavy burden that use of written protocols and improvements in hospital logistics failed to alleviate.<sup>28</sup>

Last, and perhaps above all, the need for thoracotomy frustrated hopes that resuscitation could be performed successfully outside the hospital. Since the 1930s, several electric power companies had started financing research into methods for scene-of-accident resuscitation that could be used in victims of electrocution. Ventricular fibrillation was rapidly identified as a major cause of sudden death. As early as 1933, Kouwenhoven developed an internal defibrillator, which was used successfully for the first time in a human in 1947 by Claude Beck. After World War II, Kouwenhoven continued his work under the sponsorship of Blalock, who was Chairman of the Department of Surgery at The Johns Hopkins Medical School in Baltimore. In 1958, Knickerbocker, who was working with Kouwenhoven at the time, serendipitously discovered that applying the electrodes of a defibrillator to the chest wall of dogs caused a sharp increase in blood pressure. He found that by repeating the compression of the chest he could restore a pulse. This finding was rapidly exploited by Kouwenhoven's team: "It was found that a dog could be maintained viable for a period of ten minutes by the application of rhythmic pressure on the lower third of the sternum."<sup>29</sup> On February 15, 1958, Bahnson successfully resuscitated a 3-yr-old child using this method. Jude was then asked by Blalock to evaluate the method in 20 patients, in some instances in combination with artificial ventilation. He was successful in

every case. Two years later, the first prehospital closed-chest cardiac massage was performed in Baltimore.<sup>1,26,29</sup> The time when internal cardiac massage performed by the surgeon in the operating room reigned supreme was drawing to an end. Chance and circumstance were ripe for closed-chest cardiac massage to arrive on the scene. The compelling needs of history irresistibly turned the spotlight back to this forgotten technique.

Within a few months, the foundations of modern resuscitation had been laid. Improvements were rapidly made in the other components of the management of cardiopulmonary arrest. The final step was to bring together and organize all the new knowledge in a global cardiopulmonary resuscitation protocol.<sup>30</sup> The first guidelines were issued by the American Heart Association's Cardiopulmonary Resuscitation Committee, which was set up in the early 1960s by Jude, Elam, Gordon, Safar, and Scherlis.<sup>26</sup> Although further progress was made subsequently in a process that will no doubt extend far into the future, this integration of multiple pieces of knowledge from many different areas into a rational whole was the finale to what can be only called a revolution. The end result of this process was to give full potency to each of the components of cardiopulmonary resuscitation. The concept of modern resuscitation based on global management was born. Although Kouwenhoven, Knickerbocker, and Jude did not invent cardiac massage, they grasped its importance. They were the agents of a rediscovery that went along with the flow of science, in itself a sizable achievement for which they certainly deserve credit. Furthermore, the route traveled by cardiac massage from discovery to oblivion to rediscovery is instructive. "We and future generations [of] researchers should learn from history to avoid reinventing the wheel, proving the obvious over and over again, and missing clues for potential breakthroughs."<sup>26</sup> History puts the present into perspective, teaches us to distance ourselves from novelty, and offers hope that the future will not bring a repetition of past mistakes.

The authors thank G. Knickerbocker and Professor J. Lassner, M.D., for their comments, and H. Böhrer, M.D., D.E.A.A. (Heidelberg University, Germany), for his contribution regarding their bibliographical research.

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