VACUUM-ASSISTED DELIVERY

The History of Vacuum Extraction

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T Malmström

GC Bird

The Malmström cup

The Bird posterior cup

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The vacuum principle may first have been applied in surgery by Hildanus (1632) using a leather sucker in the treatment of depressed skull fractures in infants[1]. Ambroise Paré applied the same principle with a cupping-glass to treat a depressed skull fracture in an adult in 1655[2]. The first attempted obstetrical application was by James Yonge, surgeon to the Naval Hospital in Plymouth, England. His account appeared in the Philosophical Transactions of the Royal Society of London[3]:

> *"In November 1705, I was call'd to deliver a woman 30 years old, who had 4 days laboured in vain to bring forth her first child: The head, being too big for the passage, stuck immoveable at the os pubis; so that I could neither fasten a crochet, nor draw it out by a cupping-glass fixt to the scalp with an air pump."*

When the procedure failed, he was forced, with the assistance of his son, to carry out a destructive operation on the infant's head to assist delivery[3]. The next reference to this technique was almost a century later in 1794 when Saemann of Jena wrote a brief report in which he described a dream as follows[4]:

> *"I saw in a dream an air pump wherewith one can seize the head of an infant without injury to mother or child. The pump was made of brass and had a covering of rubber with ventilators. This is a dream which might come true."*

There is no evidence that this dream did come true in Saemann's lifetime - hence the modern expression 'In your dreams.'

Neil Arnott (1788-1874), a Scot, received his education at Marischal College, Aberdeen and St. George's Hospital, London. He practised medicine in London but had an exceptionally broad scientific interest and intellect. In the 4th edition of his Elements of Physics or Natural Philosophy, published in 1829, he outlined the principles of a pneumatic tractor[5]. Later in the same work he suggested this be applied to assist delivery of the fetus.

> *"We have spoken....under the name of pneumatic tractor, of a circular piece of leather, or similar soft substance, kept extended by included solid rings or radii, as being adapted to some purposes of surgery. Now it seems peculiarly adapted to the purpose of obstetric surgery, viz, as a substitute for the steel forceps, in the hands of men who are deficient in manual dexterity, whether from inexperience or natural inaptitude."*

He then goes on to put forward the argument that would be echoed some 150 years later, namely, that the use of the vacuum would require less training and skill than the forceps to be used with safety[5].

> *"The forceps to be well and safely used, require address, which even the naturally dexterous man cannot possess without a certain degree of continued practical familiarity with it; and except in large towns, a man must be very unfortunate in his practice who often requires it: hence, the really small number of persons who use it well."*

There is no record or evidence that Arnott ever actually used a pneumatic tractor for clinical purposes.
It would be another 20 years before James Young Simpson of Edinburgh would acknowledge the work of Arnott and apply the same principle in obstetric practice. In a short presentation to the Edinburgh Obstetric Society in December 1848, Simpson also acknowledged the work of Hildanus and Paré in applying the principle of suction to the head of infants to correct depressed skull fractures. In his first published report, in February 1849, On a Suction-Tractor; or New Mechanical Power, as a Substitute for the Forceps in Tedious Labours (Fig. 1), Simpson outlined the common problem of a protracted second stage of labour6. Drawing upon observations in nature he said:

> *"If we could fix upon the exposed portion of the foetal scalp the suctorial disc of a limpet or cuttle-fish with the usual force with which they adhere to the sea rocks to which they are attached, we would have, in many cases, a power sufficient to enable us to apply by them the necessary amount of extractive force".*

He outlined the vacuum principle and the great power exercised by atmospheric pressure upon the surface of solids when the air between the attaching and attached body is removed, stating this was equal to 15 pounds per square inch when the vacuum was perfect. He reasoned:

> *"Such an arrangement and apparatus may be imitated by art; and when rendered more perfect and complete, may perhaps give us a simpler and safer obstetric power for some cases than even the forceps"[6].*

In the same edition of the London Medical Gazette in which Simpson's earlier paper was published in full7, correspondence from Frank Haddey James of Exeter endorsed Simpson's work and said he had a similar idea with a

> *"....close syringe tube, with a well adapted piston as for a stomach pump; let the termination be introduced into the vagina and applied to the child's head; let the piston be withdrawn, so as to create a vacuum and fix it to the child's head.... The large bow handle would enable the accoucheur to apply a considerable amount of force assisted by each pain"[8]*

James was a prominent member of the medical profession and one of the founders of the British Medical Association. It seems that James never constructed or used such an instrument and in his correspondence he was not claiming priority but stating that, independently, both he and Simpson had come to the same conclusions. He had, he said,

> *"not the slightest intention of lessening Professor Simpson's credit to the discovery of this method of treatment...."8.*

However, correspondence in the London Medical Gazette from another physician, James Mitchell, took an entirely different tone[9]. Mitchell, who had attended Simpson's lectures in midwifery in 1847-48, claimed that it was he, in a written answer to an examination question, who had outlined the principles of the air tractor and its construction. Mitchell recalled that Simpson, in one of his lectures, had discussed the principle of the leather sucker as suggested by Neil Arnott but had been unable to get it to fix to the child's head. He claimed that Simpson had challenged the class to come up with a method of successfully applying the traction principle to the fetus. Mitchell said that he had done so as part of his answer to an examination question and that he had included a diagram of the 'air-pump'. Simpson replied that he had never seen the examination papers as they were marked by one of his junior staff9. This was later corroborated by Mathews Duncan[10]. Apparently, the examination papers were submitted for a prize, with the author's anonymity maintained unless he won the prize - which Mitchell did not. Those papers that were not successful were returned to the examinee. There is some support for Simpson's position in that the idea of an air-tractor had occurred to him as early as 1836[11]. In later correspondence, one Robert Patterson recalled:

> *"....I have a most clear and distinct recollection of the origin of your idea regarding the air-tractor. In passing along the street together one afternoon in the summer of 1836, we happened to come upon a group of boys busily occupied lifting large stones with round pieces of leather wetted, a cord being attached to the centre, and commonly called suckers in this place"[11]*

Simpson continued to refine his original extractor:

> *"I have been up for three nights working as I am here.... I showed it last Wednesday to the Medical-Chirurgical Society. The experiments went off beautifully. I fixed a small tractor to the palm of my hand and lifted up with it an iron weight of 26 pounds. It could lift double.*

> *Dr. Margulies of St. Petersbourg Court doubted if it would really answer in practice. Well, I took him and others down a few days ago to see a baddish case and fixed the tractor on. The operation was successful. The Russian danced with joy, crying, "c'est superbe, superbe, c'est immortalité à vous"*[12].

Not all of the comments of those who read Simpson's report were praiseworthy. The Editor of the London Journal of Medicine wrote[13]:

> *"We much fear that this proposed substitute for forceps may only lead to disappointment. We also dread the infant's scalp being torn off or a parietal bone dragged out. Our fears may be visionary and certainly the communication of Professor Simpson is most deserving of attention. Before approving of the proposal, we must wait to see it fully tested in practice".*

Simpson later acknowledged that improvements were needed:

> *"I believe that the construction of the air tractor is still very far from being so perfect as it will yet be rendered"*[14]

- although he did not publish again on his air-tractor, or make reference to it in his later writings. The immortality that the Russian physician predicted came, not from Simpson's development of the air tractor, but his lasting contribution to the relief of pain for women in labour following his introduction of chloroform for that purpose one year earlier[15,16].

In 1857, Soubhy Salh from Paris described a vacuum instrument that could be used both to assist delivery and to evacuate the contents of the fetal skull following perforation. It consisted of a rubber cup with a separate vacuum pump that was attached after application. There is no record of this instrument in clinical use[1]. Herbert Stillman of the United States described, in 1875, a complex instrument which consisted of an oval cup with an attached vacuum pump and peripheral dilators. The intention was to pass the cup through the incompletely dilated cervix in arrested labour, complete the dilatation of the cervix, and apply traction with "sufficient force to ensure extraction". This instrument received a patent in the United States on February 23, 1875, but there is no record of it having been used in clinical practice[1].

The next publication on the topic came in 1890 from Peter McCahey of Philadelphia[17]. This was a published report of a demonstration before the Philadelphia County Medical Society on November 26, 1890. McCahey claimed that he was unaware of Simpson's work until after he had devised a similar instrument. He described his atmospheric tractor as "....a cup or concave disk of rubber or other air-tight flexible material, applied to the child's head, and creating a vacuum within or beneath, so that it will be firmly affixed to the head by atmospheric pressure and then making traction on the handle of the cup or disk". He was not modest about his expectations for this instrument, claiming "With it the physician can dispense with anaesthetics and reduce the expulsive stage of labour to a few minutes, instead of hours. The agony of child-birth will be reduced to an infinitesimal degree without incurring any risk or inflicting any injury on either the mother or the child, and many lives will be saved which would otherwise be lost." He reported he had "....used the Tractor in five cases and in each case effected delivery with it in five minutes.... an instrument capable of producing such beneficial results is certain to be universally employed within a comparatively brief period"[17]. At the meeting McCahey gave a dramatic demonstration of his tractor on a three week old infant who, in the pre-informed consent era, had been brought along for this purpose. Apparently he "affixed the tractor on the head of an infant three weeks old, and....lifted it up in the air two or three times, the tractor remaining in position all the time and the child apparently suffering no pain." McCahey may have been the first to point out the importance of flexion in vacuum assisted delivery:

> *"The large amount of force apparently required in some cases is because it is misdirected. The head is not properly flexed, and traction is exerted in a direction that would tend to pull the occiput through the pubic symphysis, instead of under the pubic arch...."*[17].

The first half of the 20th century saw a series of innovative investigators produce a variety of vacuum extractors but their application did not proceed much beyond the level of their own enthusiasm. The first contribution from Germany came from Dr. Kuntzsch of Potsdam in his 1912 paper Concerning Assisted Delivery with my Vacuum Cup[18.] Kuntzsch stated:

> *"I have given myself the task to see whether, other than the use of forceps, there are other forces or mechanisms to help in the extraction of the infant".*

He described a rubber and metal cup with an attached air pump which was constructed by Dr. Hermann Rohrbeck's company in Berlin. He used a manometer to assess the suction required and carried out a number of tests in the laboratory and on stillborn infants. He goes on to describe two cases in which he successfully used the instrument, one breech and one cephalic delivery. He felt the instrument held promise and that further study was required[18]

Dr. Alberto Gladish published a brief report from Buenos Aries in 1933[19]. He described his "Neumoceps" as an ovoid cup of reinforced rubber with a detachable hollow handle. The vacuum was created by depressing the cup against the head to expel the air. The hole in the hollow handle was then covered with the finger to maintain the vacuum. The brief report describes the instrument and suggests that further reports on its use would follow, but none did.

In 1939, Richard Torpin of Augusta, Georgia reported on his early experience with his 'suction cup', originally presented before the Richmond County Medical Society on December 16, 1937[20]. He described the purpose of his cup as:

> *"to provide a device which will fit closely upon the head of the fetus and protect it from injury and deformation while at the same time, permitting equalization of the suction. A further object is the provision of such a device which may be readily folded for insertion and which may be readily manipulated to any position for application regardless of the position of the head of the fetus"[20.]*

Apparently his prototype was a four inch diameter toy rubber ball cut in half with the inner surface studded with projections from tire patches, harking back to the observation by Simpson that the lining of the suckers of cuttle-fish contained projections. Torpin reported 10 cases of delay in the second stage of labour in which he had successfully used his extractor. However, later he apparently encountered many failures and abandoned its use[21.]

In Normandy, a French general practitioner, Yves Couzigou, was the first to introduce the term 'ventouse' for the vacuum extractor[22]. He presented his work to the Medical Society of Paris in 1947. He introduced a number of innovations with a straight-sided aluminum cup and a portable hand pump with a waste trap for amniotic fluid and blood placed between the cup and the pump. Traction on the cup was by means of four peripherally placed braided tapes so that he could vary the angle of traction to correct deflexion and asynclitism. Couzigou's ventouse was not widely used in France but became popular in Japan, where Hasegwa and Hijima (1951) added the modification of an electric pump[1]. They also described its use to assist delivery of the placenta which had been suggested by James 150 years before[8].

One of the most enthusiastic proponents of the vacuum extractor was Victor Finderle of Rijeka, Yugoslavia. This was a horn-shaped metal cup with a rubber cuff for attachment to the head or breech. The vacuum was induced with a large syringe attached by rubber tubing with a stop cock. In his first publication he described his instrument as follows:

> *"The extractor is a very simple instrument in the shape of a horn which is fitted close to the child's head or back following the inference obtained by exhaustion of air (vacuum). The child can be drawn out with the hand or it can be leaven to the weight which operates in slower time"[23.]*

He published 41 successful cases in the German literature[24] and three years later reported in the American Journal of Obstetrics and Gynecology[25]. In this report, he claimed that since October 1950 in the General Hospital at Rijeka the use of forceps had been completely discontinued and his vacuum extractor was used in 132 cases, which was approximately 3% of all deliveries. The caesarean section rate was just over 2% at that time. He concluded:

> *"there were no complications or accidents in mothers or delivered children".*

He continued using his extractor well into the 1960s but there is no evidence that it was widely adopted elsewhere in Europe[25.] Most of the early instruments aimed to deliver the infant after the cervix was fully dilated, but in the Oslo University Hospital, Koller used an instrument very similar to the Torpin design to apply continuous traction (0.5 - 1.0 kg) by means of a light weight in cases of incoordinate uterine action with delayed dilatation of the cervix[26.]

Tage Malmström of Sweden is generally and appropriately regarded as the father of the modern vacuum extractor (Fig. 2). The unique aspect of Malmström's metal cup was the in-curved rounded margin of the cup. Thus, the peripheral margin of the cup attached to the fetal scalp had a narrower diameter than the upper margin, thereby producing a 'chignon' which reduced the risk of cup detachment during traction. In the Malmström cup the suction and traction components were attached by one port in the centre of the cup. After much experimentation, Malmström introduced his prototype in 1953[27], with further refinements up to 1957[28,29] (Fig. 3). Like Koller, Malmström originally used the instrument in the first stage of labour to improve uterine action by pulling the head down onto the cervix[28:]

> *"In the first stage of labour and also initially in the second stage, the vacuum extractor can be used in cases of uterine inertia to stimulate the contractions by pressing the foetal head against the cervix. In such cases, one must of course, make a thorough investigation so that one has full information as to the cephalo-pelvic relation....In cases of uterine inertia where the fetal head is almost or completely engaged, the situation may be such, that one can not draw out the labour but is compelled to make a direct extraction. At this point, the vacuum extractor takes the place of high or mid high forceps, or it can make the situation much easier for a subsequent forceps delivery by bringing the head into a better position."*

Tage Malmström (1911-1995) was born in Malmö, Sweden[30,31]. After qualification in medicine at the University of Lund in 1940, he initially worked as a surgeon and then specialized in obstetrics and gynaecology. He worked in the Sahlgrenska Hospital in Gothenburg which is where he developed his vacuum extractor - the first such device to receive widespread international acceptance. Others modified Malmström's cup. Both Halkin in Liege, Belgium[32] and Løvset of Bergen, Norway[33] separated the suction and traction ports to improve the manoeuvrability of cup application in transverse and posterior positions of the fetal head. Chertkoff[34] and Saling[35] made locally applied modifications in Argentina and Germany respectively.

The next significant development came from Geoffrey Bird (1922-2001), born in England, who worked in Kenya, Australia and Papua New Guinea (Fig. 4). His idea was to separate the traction and suction ports to reduce the leverage on the cup during traction and thereby diminish the risk of cup detachment[36]. He emphasised the importance of accurate cup placement as the median application over the flexion point, which had previously been alluded to by McCahey[17]. Because of the difficulty in placing the cup over the flexion point in deflexed occipito-transverse and occipito-posterior positions, Bird further modified the cup so that the suction port originated from the lateral margin37 (Fig. 5). This so-called 'OP' cup facilitated placement laterally and posteriorly in the vagina over the flexion point. Further developments included scalloping the centre of the cup to decrease the distance of the traction point from the fetal head. The latest generation Bird cup was developed in the early 1980s with cord traction on the lateral aspects of the cup to bring the traction point even closer to the scalp and reduce the risk of detachment38. George O'Neil in Perth, Western Australia, added a curved rod to the top of a Bird-type cup upon which the traction

cord could rotate thereby reducing the divergence to the perpendicular during traction[39].

In the 1960s and 70s the Malmström vacuum extractor, or modifications thereof, achieved considerable popularity in Scandinavia, Europe, Africa and Asia. Part of the incentive for its use was, at least the perception, that it required less training for safe use than the obstetric forceps, as suggested by Arnott some 150 years earlier[5]. The other advantage was the reduced maternal trauma and the fact that it could be performed under local anaesthesia more readily than forceps delivery. Despite these apparent advantages vacuum extraction with the metal cup never achieved popularity in North America, presumably due to the rather dramatic chignon and the growing environment of obstetrical litigation[40]. In the early 1970s, in an attempt to reduce scalp trauma attributed to the metal cups, experiments were undertaken to develop the vacuum cup with softer material - in a sense returning to those of the early 20th century. The first of these was designed by Dr. Kobayashi, Professor of Obstetrics and Gynaecology at Tokyo Medical School, and produced as the Kobayashi Silastic cup[41,42]. John Wood of Oregon also reported favorably on a new plastic disposable vacuum extractor cup in 150 cases[43]. Erik Uddenberg from Sweden, manufacturer of the Malmström and Bird instruments, produced a European version, the 'Silc cup', in 1984[41]. Many of the features of this cup were similar to those previously described by Torpin[20].

By the early 1990s there was growing disenchantment with the high failure rates of achieving delivery with the soft vacuum cups. These failure rates could be up to 25%[44-46] compared to the failure rate of 1-3% achieved with the Bird modification of the Malmström cup37. Thus, in the 1990s cups made of harder plastic were developed including one, the 'M-cup', based on the Malmström design[44]. Aldo Vacca of Brisbane worked with Bird in Papua New Guinea and later carried out the first randomised trial comparing vacuum extraction and forceps delivery in Portsmouth[47]. He has incorporated the principles of Bird's posterior cup into a new rigid plastic device, the OmniCup. This disposable device has a thin flexible suction/traction tube attached to the centre of the cup via a recessed groove[48]. The narrow depth of this cup facilitates its application over the flexion point in transverse and posterior positions[49].

The use of the vacuum extractor as a substitute for forceps in assisted vaginal delivery has evolved considerably over the last 40 years, such that it many countries the vacuum extractor has almost replaced forceps. Two quotes from the prominent proponents in the early 19th century continue to resonate. Those who Arnott described as "deficient in manual dexterity, whether from inexperience or natural inaptitude" will continue to tarnish the reputation of both the forceps and the vacuum extractor. Simpson's words also remain relevant:

> *"I believe that the construction of the air-tractor is still very far from being perfect as it will yet be rendered".*

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