

Dr Potts' Blue Children

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Abstract

This narrative article aims to explore the life of Willis John Potts, a surgeon and pioneer in the field of pediatric cardiovascular surgery. Between the 1950s and 1960s, his work contributed enormously to the development of new surgical techniques and instruments; nevertheless, he remains a largely forgotten figure. Yet his determination and organizational skills enabled rapid and fundamental advances in surgery. Historical research, utilizing biomedical databases, represents an attempt to do historical justice to Potts: although unusual, this methodology has yielded a wealth of indexed information on Potts, including publications by him and his key collaborators. An analysis of Potts' surgical career is also an analysis of the development of both pediatric surgery and, above all, cardiac surgery: the instruments and procedures he devised have found applications well beyond the exclusively pediatric field.

Keywords: Willis John Potts, History of Surgery, Pediatric Surgery, Cardiovascular Surgery, Surgical Instruments, Congenital Heart Disease

Wisconsin to Pediatric Surgery

Potts' scissors are one of the most widely used microsurgical scissors in operating theatres; from plastic surgery to cardiac surgery, and across thoracic and vascular disciplines, they are an indispensable tool for managing blood vessels. Yet the story of the man who invented them is unknown to most people today. Willis John Potts was born in Sheboygan County, Wisconsin, in 1895, into a Unitarian Christian family; his faith always played an important role in his life, inspiring him to devote himself to children. The Potts family owned a farm near Cedar Grove; on his father's death, Willis had to run the farm alongside his elder brother but managed to save enough money to enroll at a private school, obtaining a diploma that

subsequently enabled him to attend college. In 1917, when the United States entered the First World War, Potts enlisted in the army and spent a year on the French front (Baffes, 1987). In 1919, upon his return from Europe, Potts enrolled at Rush Medical School in Chicago, where he graduated with a degree in medicine in 1924, before practicing briefly in Oak Park, on the outskirts of the city. The very next year, he decided that surgery was his field of interest; consequently, he attended the Presbyterian Hospital, where he qualified in 1928. To complete his surgical training, Potts spent the period 1930–1931 undertaking postgraduate training in Frankfurt am Main, from which he returned having learnt much from the German school of surgery; upon his return to the United States, he settled in the Chicago suburbs, where he practiced as a

surgeon until 1940 (Baffes, 1987; Riker, 1968). The war once again disrupted his life on 7 December 1941, with the Japanese attack on Pearl Harbour. In the wake of the US national mobilization, some of the medical and nursing staff from West Suburban Hospital in Chicago volunteered to form the 25th Evacuation Hospital: among them was our very own Potts (Baffes, 1987). After a period of training and preparation, the medical unit of the 25th Evacuation Hospital, with its complement of personnel and equipment, reached the South Pacific theatre of war by ship in November 1942, arriving at Port Vila, before continuing further north to the island of Espiritu Santo. 1,000 km to the north-west the bloody and fierce campaign of Guadalcanal was underway, and surgeons and nurses were needed to treat the marines fighting there. Given the proximity of the 25th Evacuation Hospital's destination to the bases of the Imperial Japanese Navy, and fearing air raids, the ship carrying the medical equipment remained at Port Vila: the personnel sent to Espiritu Santo had to 'make do' with the buildings, facilities, furniture and shelving available, and physically construct the military hospital themselves, with the help of scarce medical supplies provided by the US Navy. After months of work in the stifling jungle, with the help of soldiers and local inhabitants, the staff managed to complete the facility, which had a capacity of 750 beds (South Pacific WWII Museum, n.d.). During the war years, Potts was promoted to the rank of colonel in recognition of his organizational skills and surgical expertise. In 1945, towards the end of the war, he came across a book that would prove pivotal to his life: *Abdominal Surgery of Infants and Childhood*, published by Gross and Ladd in 1941 (Baffes, 1987). He was so captivated by the nascent field of pediatric surgery that he decided that would be his path (Baffes, 1987). Pediatric surgery as an independent and autonomous branch was in its infancy, having emerged only once reliable knowledge, expertise and techniques for the care of children had become available. The prevailing practice was still to admit young patients to surgical wards alongside adults, as, according to some "...surgical conditions should be treated in major hospitals" (Hazeltine & Hirsh, 2022). The first pediatric surgical ward was established at the Royal Edinburgh Hospital for Sick Children in 1887. Even in

the early years of the 20th century, there were no specialist training programs in pediatric surgery, although there was pressure for children to receive dedicated surgical care. It was the years immediately following the Great War that brought about change, particularly in the Anglo-Saxon world, thanks to the work of William E. Ladd (1880–1967), who, deeply moved by the children involved in the Halifax explosion of 1917, decided to devote himself entirely to them at the Children's Hospital in Boston, where he dedicated himself to treating numerous conditions such as biliary atresia and obstruction, pyloric stenosis and other intestinal malformations (Hazeltine & Hirsh, 2022). His work earned him the title of Surgeon-in-Chief at Boston Children's Hospital in 1941, whilst he was also launching the first specialization course in Pediatric Surgery; and it is precise here that our Dr Potts comes into the story.



Figure 1. Willis John Potts (1895–1968).

The “Blue Children” and the Potts Anastomosis

Upon his discharge from military service

in 1945, Potts returned to Chicago, where he secured a post at the Children's Memorial Hospital (Baffes, 1987); at the time, the hospital mainly performed laparotomies, appendectomies and pyloromyotomies, but Potts, having read the section on congenital heart disease in Gross and Ladd's textbook, was determined to embark on something new: to establish a pediatric surgical training program focused on cardiac and vascular defects. The following year, he was also appointed to the post of Professor of Surgery at Northwestern Medical School (now the Feinberg School of Medicine at Northwestern University) (Baffes, 1987; Riker, 1968). Potts's idea at this point was to establish a surgical residency training program based on the best available knowledge and techniques, with a focus on vascular techniques in pediatric patients. But how could he achieve all this, given that at the time this field of interest was completely unknown and groundbreaking? First, Potts spent three months at Boston Children's Hospital to learn about its organization; he studied its structure, which was divided into specialist departments, and, upon returning to Chicago, set about putting his plans into action (Baffes, 1987; Riker, 1968). First and foremost, expertise and professionals were needed: therefore, thanks to his connections and his character, Potts attracted many experts such as orthopedic surgeons, anesthetists, urologists, abdominal surgeons and plastic surgeons. However, to establish an advanced and modern pediatric surgery program, research facilities were also required; Potts insisted on—and succeeded in—converting part of the pediatric hospital's infectious diseases ward into a research laboratory, equipped with a sterile operating theatre and an animal facility (Baffes, 1987). To tackle the challenge of major vessel surgery, Potts had to consider building his own team of collaborators; upon his return to Chicago in 1945, he had already met Stanley Gibson, a nationally renowned pediatric cardiologist famed for his diagnostic skills, to whom was added Joseph Boggs, Director of the Pathology Department and a leading expert on congenital heart defects (Baffes, 1987). Thanks to his collaboration with Gibson and Boggs, a program for the diagnosis and treatment of congenital heart disease in children was launched. From among the young surgeons working with him, Potts chose

Sidney Smith as his most trusted colleague: his skill at performing vascular anastomoses and in devising new approaches to surgical challenges had made him indispensable. To give an idea of the enthusiasm and passion Potts poured into his project, just over a year had passed since his arrival at Chicago Children's Memorial Hospital (Baffes, 1987). It is also important to understand the context and scope of the projects Potts aspired to: in 1946–1947, cardiovascular surgery on pediatric patients was at the very limits of what was feasible. In those years, the only procedure made possible was the correction of tetralogy of Fallot, also known as 'blue baby syndrome' due to its cyanotic nature; the clinical-pathological profile of this malformation, supported by specific diagnostic tests, had been presented by the American cardiologist Maude Abbot as recently as 1936, and in 1945 Alfred Blalock, at the suggestion of his colleague, the cardiologist Helen Taussing, introduced a surgical procedure to alleviate the anoxia caused by pulmonary stenosis or pulmonary atresia through an anastomosis between the subclavian or anonymous artery and the right or left pulmonary artery (Dionigi, 2017, p. 956). While finalizing the organization of his surgical department, Potts kept himself constantly up to date and, together with his team, devised a different approach to correcting blue baby syndrome.

On Friday 13 September 1946, Potts's team performed the first operation to correct Tetralogy of Fallot on a young girl, Diane Schnell, by creating an aorto-pulmonary anastomosis. Technically, the procedure was less complex than the one developed by Blalock in Baltimore, which involved transection of the right subclavian artery and anastomosis onto the right pulmonary artery (Dionigi, 2017, p. 956), but it required direct manipulation of the large vessels, with the descending thoracic aorta clamped for the time necessary to perform the anastomosis (Potts et al., 1946): the risk of spinal cord injury and ischemia, leading to paraplegia, was very real. The young patient survived the operation and was discharged from hospital 19 days later (Baffes, 1987; Riker, 1968). Two factors had made Potts's operation possible; firstly, the technique had been simulated and perfected at the research laboratory of the Children's Memorial Hospital in Chicago: Potts's team

practiced the anastomotic technique on several dogs (Baffes, 1987). But above all, Potts had an ace up his sleeve: a surgical instrument specially made by his neighbor; whilst living in Oak Park, Willis Potts lived next door to Bruno Richter, a talented craftsman who designed and manufactured surgical instruments for a local medical supplies company (Baffes, 1987). Needing to find a solution that would allow adequate blood flow to the medullary arteries, Potts, his colleague Smith and Richter set to work in the summer of 1946 to find a solution. Richter found the solution by modifying an eyelid retractor: the resulting instrument allowed blood flow to the lower part of the body whilst 'isolating' the area affected by the suture; several versions of this hemostat were produced, in various sizes to better suit the different calibers of the vessels (Potts et al., 1946; Zeller et al., 2022).

Instruments That Changed Surgery

Richter's contribution was not an isolated case; in 1947, Potts read about the operation performed by Robert Edward Gross, a surgeon at Boston Children's Hospital, to close the ductus arteriosus (Gross, 1947). This vascular malformation, which connects the left pulmonary artery or the pulmonary trunk to the descending thoracic aorta, is quite common in premature or low-birth-weight infants, in whom it can lead to a critical clinical condition (Dionigi, 2017, p. 948); its correction by ligation had already been attempted in 1938 (again by Gross himself), but the 1947 procedure involved the use of delicate clamps (such as Mosquito clamps) to clamp the two vascular ends of the ductus, followed by its transection and the subsequent placement of terminal sutures on the two vascular stumps. Potts soon recognized a problem: the use of surgical instruments designed for adult patients on the cardiovascular tissue of a pediatric patient exposed the latter to numerous risks, both in terms of the reliability of vascular clamping and the potential for tissue damage. After giving it some thought, he once again turned to his neighbor for help: together with Richter, they devised a new class of instruments, the vascular clamps (Baffes, 1987; Moritz et al., 2022; Potts, 1948) (Fig.2). Characterized by a bite with a longitudinal groove capable of

sealing the vessel wall without damaging it, the idea came to Potts whilst he was casually observing the packaging of an elastic bandage, and Richter skillfully designed and then constructed the vascular clamp (Baffes, 1987). Following the usual experimental work on dogs, Potts used the clamp he had devised with Richter on his patients: 16 children aged between 2 and 13, in whom the ductus was dissected and subsequently sutured, with no deaths or post-operative complications. These instruments heralded a new era in large vessel surgery (Potts, 1948).

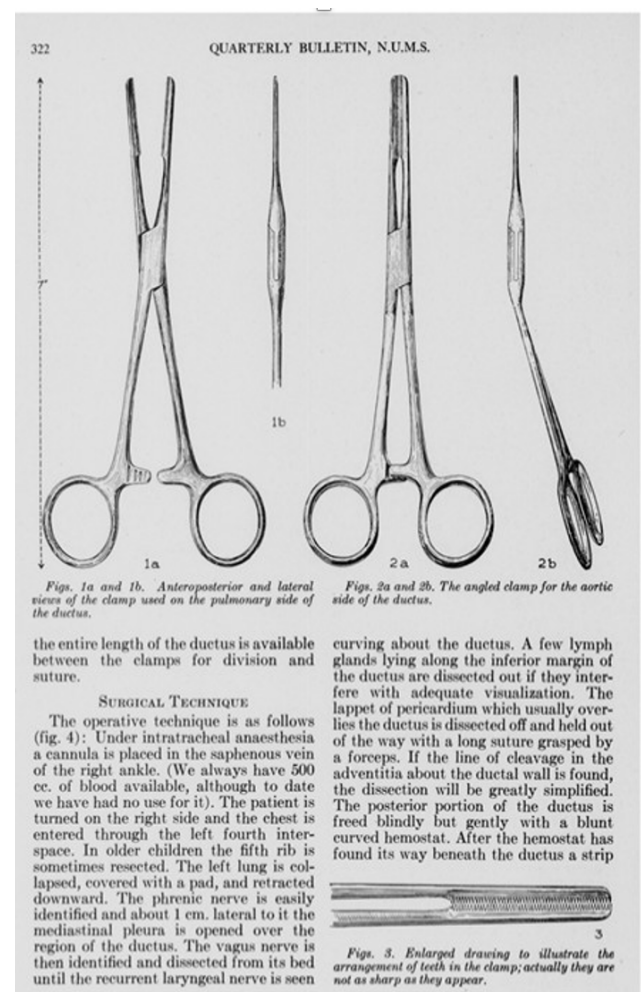


Figure 2. Original illustration of the vascular clamp developed by Willis J. Potts and Bruno Richter.

Potts, specializing in the field of large vessels, made a significant contribution to the technique of vascular anastomosis. At the time, the preparation of arterial sutures was still considered a limitation: the only method available was the application of venous

grafts to arterial trunks, which considerably restricted both the scope of application and the technical options (Moritz et al., 2022). Potts devised numerous instruments to facilitate surgery on arterial trunks: during those years, he commissioned the craftsman Richter to produce many surgical instruments. First and foremost were his famous vascular dissection scissors, with angles of 25°, 45°, 60° and 90°, designed for high-precision cutting and dissection of blood vessels (Fig. 3). He also had thin, delicate surgical forceps made, capable of gently holding arterial tissue without damaging it; the use of vascular clamps designed for the safe occlusion of arterial segments also revolutionized vascular surgery. Potts, with the help of his trusted colleague Richter and his collaborators, devised surgical instruments that are still in daily use in operating theatres today (Baffes, 1987).

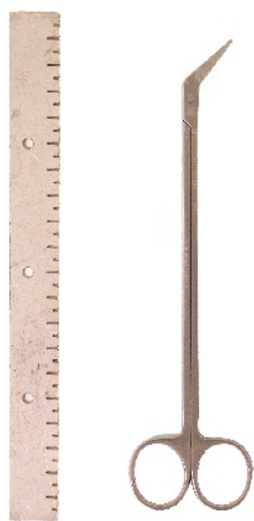


Figure 3. Potts vascular dissection scissors.

In the fields of vascular surgery and cardiac surgery, Potts also turned his attention to adult patients, developing (again in collaboration with Richter) the valvulotome. By the first half of the 1950s, cardiac surgery was booming: numerous centers of excellence were emerging, such as those in Toronto and Montreal, the Karolinska Hospital in Stockholm, Guy's Hospital in London and the Ospedale S. Giovanni Battista in Turin (Actis Dato & Actis Dato, 2020; Castañeda, 2005). It was precisely thanks to the concurrent work of Charles Bailey, Dwight Harken, Russell Brock and Achille Mario Dogliotti that closed-heart mitral commissurotomy was introduced during

those years (Actis Dato & Actis Dato, 2020). In 1952, Brock described his pioneering work on transventricular pulmonary valvulotomy (Brock, 1952); this was a closed-heart surgical procedure to correct pulmonary valve stenosis. In this case too, Potts carefully studied the work of his London-based colleague and considered that the procedure performed by Brock was very interesting, but that the profuse bleeding—linked to the opening of the heart chamber to allow the retractor to enter—was incompatible with patient safety. Potts and the expert Richter then devised a specialized instrument: the valvulotome. Fitted with retractable blades whose opening could be adjusted via a selector switch in the handle, the instrument was inserted through a small external incision in the right ventricle; guided by the tactile sensation of his fingers, the surgeon inserted the tip of the valvulotome through the pulmonary valve and ‘incised’ the valve itself with the retractable blades. Once the procedure was complete, the instrument was withdrawn and the small access point on the ventricular wall closed: a potentially dangerous procedure which, thanks to Potts and Richter, was transformed into something relatively simple (Baffes, 1987; Glenn, 1987).

Innovation in Congenital Heart Surgery

Between 1954 and 1955, Willis Potts took an interest in the work of Alfred Blalock and Rollins Hanson at Johns Hopkins University: the surgical correction of transposition of the great arteries (TGA). This condition is a cyanotic congenital heart defect, characterized by atrioventricular concordance and ventriculo-arterial discordance, with the aorta arising from the right ventricle and the pulmonary artery originating from the left ventricle. The resulting clinical condition is clearly serious and, in cases associated with additional heart defects, becomes incompatible with survival in the medium term (Dionigi, 2017, p. 960). The two surgeons at Johns Hopkins had been working on this since 1948, when they proposed the creation of a ‘site’ for the mixing of arterial and venous blood: after studying 123 cases of TGV, they hypothesized the use of a surgically created atrial septal defect to allow oxygenated blood to pass into the systemic circulation (Marathe & Talwar,

2015). In 1950, the two surgeons succeeded in performing this technique – the Blalock-Hanlon septectomy – on a patient; although regarded at the time as a surgical feat, the procedure was nevertheless considered a palliative measure as it did not definitively resolve the malformation (Marathe & Talwar, 2015). Shortly afterwards, in September 1953, Walton Lillehei and Richard Varco reported on eight surgical attempts they had made to correct TGV (Glenn, 1987): in the first four operations, the surgeons had anastomosed the right pulmonary veins to the right atrium (only two out of four patients survived), whilst in the following four patients they had performed an anastomosis of the inferior vena cava to the left atrium (none of these patients survived). This is precisely where our protagonist comes in: it was 1954 and Thomas Buffes, a young trainee on Potts's course, proposed his own idea for the surgical correction of TGA (Baffes, 1987). The young surgeon's idea was to perform a venous correction using an aortic graft to bypass the inferior vena cava to the left atrium. Buffes himself recounted: "When I first presented the idea of designing a partial venous correction for transposition of the great arteries to Dr Potts, he curled his moustache, as was his habit, and fell into deep thought. After a while, he said: 'Transposition accounts for about half of the defects in cyanotic children admitted to this hospital. We haven't been able to do much for any of them, except for those special cases with pulmonary stenosis and ventricular septal defects.' He thought for a little longer; then his eyes sparkled with excitement. 'Go on, do it!' 'I shall provide the necessary funds.' And so began many happy years of research and discovery under the guidance of the master surgeon" (Baffes, 1987). There were numerous obstacles to overcome, and not just surgical ones: what material should be used to create the bypass envisaged by Buffet's idea? The technology for grafts using Dacron or polytetrafluoroethylene (PTFE) prostheses was still in its infancy: it was not until 1952 that Voorhees and his colleagues at Columbia University had used tubular polyvinyl chloride grafts in animal models, with results deemed contradictory (Lillehei & Varco, 1953). As no other materials were available, it was decided to use human aortic tissue: under Potts' supervision, Buffett and his colleagues began to develop a method for harvesting, sterilizing and preserving human

aortic homograft, which were freeze-dried and vacuum-packed; only once this initial difficulty had been overcome was it decided to move on to the second stage: studying the use of aortic tissue and any possible complications or difficulties in animal models. To achieve this, species-specific aortic homografts were created and used to bypass the inferior vena cava in several puppy dogs; the team then waited for the dogs to reach full maturity to check that there were no signs of obstruction or tissue damage. Given the very promising results, Potts decided that the procedure could be attempted on a select group of patients: on 6 May 1955, the operation was performed with a successful outcome and was published the following year in an article which, strangely, listed only Baffes as the author (Baffes, 1956). By 1960, a retrospective study had been published – again authored by Baffes but with Potts among the co-authors – to illustrate the 5-year survival rate following the introduction of the technique he had devised, which had stood at 29 per cent out of 117 cases treated (Baffes et al., 1960). The procedure devised in collaboration with Potts remained the treatment of choice for newborns with transposition of the great vessels for the following 10 years (Marathe & Talwar, 2015), although Baffes himself had already planned in 1955 to modify the surgical technique he had devised, so that the superior vena cava would now be exchanged with the left pulmonary veins. It is worth noting that during the two-year period 1954–1955, another young researcher at the Chicago Children's Hospital, Harold Albert, encouraged by Potts, devised a method for correcting TGA by implanting a prosthetic transseptal cardiac shunt: this unidirectional 'window' would be achieved by creating bilobed flaps of the interatrial septum, with each lobe covering the orifices of the vena cava. Albert published his canine experiments in 1955 but was unable to replicate them clinically (Albert, 1955). His idea nevertheless led to the concept of interatrial switching, which was subsequently developed by William Thortontont Mustard and colleagues in Toronto in 1963 (Albert, 1955; Konstantinov et al., 2004).

Extracorporeal Circulation and Open-Heart Surgery

These were years of major scientific and

technical discoveries and applications, particularly in the United States; there, in fact, great strides were being made towards the development of a device that would take over the heart's normal function during these open-heart surgical procedures. The pioneering work of DeBakey and Schmidt in 1934 had led to the creation of a machine consisting of a double pump capable of oxygenating the bloodstream (Holman et al., 2022); subsequent improvements made by Henry Dale (Nobel Laureate in Medicine in 1936), Edgar Schuster, John Heysham Gibbon and Walton Lillehei, with the assistance of researcher Richard DeWall, led to Lillehei's first use of the device in the operating theatre on 13 May 1955 during open-heart surgery (Holman et al., 2022). Naturally, Potts and his team also took an interest in the subject (Potts et al., 1952); the first attempts at extracorporeal circulation on living tissue, carried out at the research center led by our protagonist, had already begun in 1951, using a Dale-Schuster pump on a number of dogs, but given the technical difficulties and unsatisfactory results, the studies had to wait until the arrival of the heart-lung machine developed by DeWall, with which over 200 experiments on animal models and six clinical trials were carried out (Riker et al., 1962). In 1958, Potts and his team focused their efforts on a disc-type oxygenator coupled with a T3 Sigmamotor pump: survival rates in animal models were 100 per cent, so they proceeded to introduce it into clinical use. Over 400 patients underwent surgery using this extracorporeal circulation system over the following four years, primarily for ventricular septal defects, which were often associated with other congenital defects such as transposition of the great arteries, tetralogy of Fallot, pulmonary stenosis, ostium primum, aortic stenosis and atrioventricular canal defects (Riker et al., 1962). Potts and his team had developed their own model of a heart-lung machine, suitable for clinical use and fully functional, but the bubble oxygenator developed by DeWall was simpler and remained in use until the late 1970s (Riker et al., 1962).

Legacy of Willis John Potts

In October 1962, Potts was awarded the Ladd Medal, which recognizes pediatric surgeons

who have made a significant contribution to infant surgery and the care of newborns and children (Baffes, 1987; Riker, 1968). In 1965, he retired from the profession; having retired, he settled in Sarasota (Florida), a town with a vibrant cultural life (Baffes, 1987). On 5 May 1968, Willis Potts died of a heart attack; he was survived by his wife Henrietta (whom he married in 1922), two sons, a daughter and 14 grandchildren (Baffes, 1987; Riker, 1968). Willis John Potts was described by his colleagues as a perfectionist who demanded the very best from others and from himself; yet he could also be impatient when he failed to achieve the desired result. He was an innovator, delighted to be able to apply the findings of his own and others' research in the operating theatre, and an unrivalled teacher, capable of explaining and expressing himself directly and clearly (Baffes, 1987). His most remarkable trait, however, was the empathy he established with his young patients, a genuine feeling that had a positive impact on both their physical and psychological wellbeing: many of his colleagues recall meetings and ward rounds being interrupted by Potts so that he could play with his young patients (Baffes, 1987; Riker, 1968). According to his pupils and students, he was an excellent teacher and mentor, always ready to pass on his knowledge to others; but he could also be very direct and blunt when the situation or the mistake before his eyes was glaringly obvious. His skill and expertise have been passed down to us through his surgical instruments, many of which are still in use today, but also through his pupils: numerous surgeons whom he trained at the Chicago Children's Hospital have continued his work, refining surgical techniques and approaches. DeBoer became a pediatric cardiovascular surgeon and professor at Northwestern University Medical School; Farouk Idriss became head of the Cardiovascular Division at Children's Memorial Hospital in Chicago, as well as a professor at Northwestern University Medical School. John Raffensberger became director of the surgical department at Chicago Children's Hospital and author of a renowned textbook on pediatric surgery. Thomas Baffes, meanwhile, became head of the surgical department at Mount Sinai Hospital Medical Centre in Chicago (Baffes, 1987).

Potts' work contributed significantly to the advancement of surgery in the second half of

the 20th century and can be summarized in three keyways:

- the development of excellence in surgical techniques. Potts demanded the very best from himself and those around him: none of his trainee surgeons were permitted to look after his pediatric patients or enter the operating theatre until they had first demonstrated their technical and practical skills in the animal laboratory. Arterial anastomoses were still in their infancy at the time: Potts improved the technique for performing them through his own instruments and skill; his students learnt a great deal from this;
- the creation of specialized surgical instruments. The instruments designed by Potts and manufactured by Bruno Richter made surgical practice safer: these were not mere adaptations but designs specifically tailored to the surgical context. This made them highly valued, so much so that they are still featured in the catalogues of numerous manufacturers today; above all, they formed the foundation upon which many other giants of surgery were able to achieve their feats;
- innovative vision. Having read the work carried out by his colleagues, Potts decided to follow in their footsteps whilst refining their surgical technique; whilst always remaining aware of his own limitations, he constantly sought to bring the best available evidence and the results of his own and others' research into the operating theatre. Potts was also a remarkable planner and coordinator: in just over a year after his arrival, starting almost from scratch, he managed to create a model of training and organization that remained unique for years. This vision was further enhanced by his forthright nature and remarkable intellectual integrity: evidence of this is that in 1955 Potts wrote an editorial in JAMA criticizing pediatric surgical care in the United States, pointing out that across the whole country only eight hospitals had pediatric surgery program run by staff trained for that purpose (Potts, 1955).

It seems incredible that, despite Potts's enormous contribution, medical historiography

has treated him rather unfairly: much of the information gathered for this account has been drawn from the bibliographies of two key articles (the most recent of which dates from 1987), whilst other documents have proved difficult to access. We therefore hope to have paid tribute to this giant of the surgical world, whose ideas and instruments accompany us every day in our daily work.

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