# Kidney Removal
# The Past, Presence, and Perspectives
## A Historical Review

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More than 140 years have passed since the first documented planned nephrectomy. Throughout all these years, people gained significant knowledge on the renal functions and diseases, and what is more, the surgical workshop underwent considerable improvement. Initially, the kidney removal operations were performed due to ureterovaginal fistulas and renal lithiasis. Later, they were executed mainly in patients with renal tumors, whereas today, the number of these surgeries tend to decrease to the benefit of nephron sparing procedures. Current nephrectomies are more and more often performed in case of organ donation, what will probably remain the most significant indication for the kidney removal in close future. While the first surgeries were executed with classical surgical methods, nowadays, after years of studies concerning nephron sparing and minimally invasive operations, we can see surgeries carried out through natural body orifices with robotic assistance. In relation to simple surgical operation based on ligation of 3 tubular anatomic structures, we can perceive the true scope of the progress that occurred in surgery. The aim of this article is to present the evolution of indications and operating techniques utilized to remove the kidney in chronological aspect.

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## THE FIRST NEPHRECTOMY

The possibility to undertake the attempt to remove the kidney in human beings was related with decades of research on the method of operation and the influence it has on physiological processes. Experiments used the model of the dog, and of the first researchers of the kidney removal issue, we can enumerate Hendrik von Roonhuysen (1672), Giuseppe Zambeccarius (1678), and Stephan Blanchard (1698). Tests performed on dogs that underwent unilateral nephrectomy revealed compensative hypertrophy of the remaining kidney and have ultimately proved that the animal with only one kidney can survive.[1]

The first nephrectomy performed on a human was executed in 1868 by a Canadian surgeon, William Hingston from Hôtel Dieu Hospital in Montreal. However, this achievement was not announced due to the failure of the surgery; the patient died on the operating table, immediately after the removal of the kidney.[2] As documents stated, Gustav Christoph Jakob Friedrich Ludwig Simon, a German surgeon who carried out nephrectomy in 1869, is the pioneer of the kidney removal surgeries. He was an expert in surgical treatment of

ureterovaginal fistulas and was the author of the so-called 'German method'. Margaretha Kleb was one of the patients operated by Simon; she was a 46-year-old patient with left-sided ureterovaginal fistula, being a complication related with surgical removal of uterus with adnexa. Simon undertook three attempts to close the fistula, but all three endeavors turned out to be inefficient. Only the left kidney removal could constitute the final solution of the clinical problem. After several dozens of experimental operations on 30 dogs, Simon decided to operate his patient. The surgeon considered sepsis as the most serious complication, yet pre-operative evaluation of the contralateral kidney function and manner of ligation of the renal peduncle were also significant problems. The surgery was performed on 2 August 1869 in Heidelberg, Germany. The patient was anesthetized with chloroform. Simon took advantage of lumbar access, mainly due to complications during abdominal operations, which were quite frequent at that time. Renal peduncle was ligated with silk suture. The surgery lasted 40 minutes and ended with success. Post-operative period was complicated with infection of the wound, pneumonia, and erysipelas. Kleb left her bed 28 days after the surgery, and she was discharged from hospital after following two months.[1,3]

Hingston and Simon were certainly the first surgeons who operated with the aim to remove the kidney. Nonetheless, even before 1868 when testing surgical specimens, surgeons sporadically found the kidney in tissue block.[4] A German gynecologist, Otto Spiegelberg, was one of those who decided to describe this event. In 1867 in Wrocław, he accidentally removed the kidney when operating echinococcal cyst. All in all, it is hard to establish the date of the first surgical kidney removal.

## NEPHRECTOMY IN THE 19TH CENTURY

The first nephrectomies finally proved that it is possible to remove one kidney in a human being and that a patient can survive with only one kidney. However, these operations slowly gained acceptance of surgeons. This was related initially with extremely high rate of peri-operative mortality, reaching even up to 50%. Simon performed his second nephrectomy in 1871. The patient died 31 days after the operation. The most frequent problems tragically complicating the postoperative course were infections of surgical wound, at that time referred to as hospital gangrene and sepsis.[5] The highest percentage of failures was observed after procedures performed in patients with a renal tumor; however, there were not too many of these operations during those days. Postoperative mortality rate due to renal tuberculosis, hydronephrosis, or urolithiasis in most of the patients did not exceed 40% (Table 1).[6]

At the end of the 19th century, Joseph Lister, being in charge of Surgical Department at King's College University Hospital in London, initiated antiseptics. Introducing activities proposed by Lister, including washing and disinfecting surgical tools and hands with carbolic acid before the operation, into surgical practice had a noteworthy result in reduction of peri-operative mortality.[7] Johann Anton von Mikulicz-Radecki from Surgery Clinic of Jagiellonian University, who introduced cotton surgical gloves in 1885 and sterile face masks covering the face of a surgeon in 1896, and William Stewart Halsted from John Hopkins University in Baltimore, who proposed replacing cotton gloves with rubber ones in 1889, followed the ideas suggested by Lister.[8,9] The year of 1886 is considered as the beginning of aseptics, since Ernst von Bergmann, surgeon from Berlin University, was the first person to perform steam sterilization in that year.[10] Increase in the number of performed surgeries, including nephrectomy, was the aftermath of the above-mentioned events. By the end of the 19th century,

**Table 1.** Postoperative mortality rate among patients who underwent nephrectomy, operated by the most eminent urologists of the 19th century.[6]

| Name of surgeon | Number of operations | Mortality [%] |
|---|---|---|
| Schede | 38 | 21 |
| Bardenheuer | 37 | 21.6 |
| Israel | 37 | 16.2 |
| Czerny | 33 | 51 |
| Thornton | 25 | 20 |
| Kuster | 14 | 28.5 |
| Tuffier | 8 | 37.5 |
| TOTAL | 192 | 27 |

more than 300 surgical kidney removals have been performed in Europe and America, whereas 55 of them were carried out on patients with renal tumor.[11]

Simultaneously, people gained knowledge on renal anatomy and surgical workshop was being perfected. In 1895, a Romanian anatomist and urologist, Dimitrie Gerota, described topographical anatomy of the kidney, including presence of renal fascia. The end of the 19th century can be also enlisted within the turbulent period related with development of surgical instruments. As far as the kidney removal aspect is concerned, instruments proposed and perfected by Jules- Émile Péan, Emil Theodor Kocher, Jean Guyon, David Satinski, and others seem to be of most considerable significance. Popularization of hemostatic clamps helped to cease bleeding from the blood vessels. Yet, what still remained to be the problem was the dangerous parenchymal bleeding, until now treated by cauterization with hot iron. In 1896, Arsène Jacques d'Arsonval was the first one to take advantage of electrocoagulation with the use of diathermy.[12]

## RETROPERITONEAL AND TRANSPERITONEAL ACCESS

Initially, the surgeries were being performed from retroperitoneal approach. In 1878, Emil Theodor Kocher, from Surgery Clinic of University of Bern, removed the kidney via transperitoneal approach, opening the peritoneal cavity with medial incision.[13] In 1913, a Norwegian surgeon, Atle Berg, modified the operation performed by Kocher. He used lateral incision and also proposed mobilization of the colon to visualize the renal peduncle better as well as to increase the security of the procedure. Berg is considered to be the first surgeon who removed neoplastic thrombus from the inferior caval vein in a patient with a renal tumor.[14]

In the light of relatively bad results of transperitoneal nephrectomy, in 19th century and in the beginning of the 20th century, the retroperitoneal access was much more frequently used. Differences resulted from high rate of abdominal complications after transperitoneal surgeries. The most often observed complications included repeatedly infection of peritoneum with critical outcome. Introduction of antiseptics to medicine and perfection of operating techniques had influence on improvement of outcomes and resulted in regained initial interest in transperitoneal access in the surgeons. At that time, the most considerable advantage of these operations lied in the possibility to visually evaluate the second kidney.

## NEPHRECTOMY IN THE 20TH CENTURY

The first half of the 20th century constituted a restless period concerning the development of suturing materials. In the face of increasing anatomic and physiological knowledge as well as surgical progress, lack of methods related with reliable vessel treatment and wound closure methods stood as one of the most noteworthy complaints reported by surgeons. In 1906, Franz Kuhn, a German surgeon, elaborated a sterilization method for chromic catgut, the first suturing material in history, which was made of ram intestine, especially for surgical needs. Two years later, Kuhn persuaded Carl Braun, a German businessman, to produce sterile catgut on a wide scale. Whereas, during the 30s of the 20th century, production of the first synthetic sutures and non-absorbable sutures was initiated.[15]

Despite the development and perfection of surgical tools, the beginning of the 20th century still faced the problem of blood loss during the kidney removal, which was insufficiently solved and caused mortal complications in hundred cases. Popularization of hemotherapy, whose history began to quicken in the beginning of the 20th century, became a solution for the problem. In 1901, Karl Landsteiner separated blood groups, while in 1910, Ludwik Hirszfeld and Emil von Dungern revealed inheritance of group features. Thereafter, physicians performed transfusions only of blood with group compliance, except for the 'O' group, which was referred to as the 'universal' group and was transfused irrespective of the blood group of the patient. In 1915, results of tests by Richard Lewinsohn provided knowledge on possibility of blood conservation

with the use of sodium citrate. Blood transfusions became simple life-saving procedures.[16]

In face of popularization concerning ether anesthesia, next to perfection of anesthetic devices and tubes used for endotracheal administration of anesthetic agents, popularity of nephrectomy increased. The discovery of penicillin was the most important event in the 20th century, which significantly increased the number of performed renal operations, but also became the propulsive power of the whole surgery. In 1928, Alexander Fleming initiated a new era of surgical treatment.

In the era of general anesthesia, efficient antibiotic therapy, developing transfusiology, vast instrumentarium, and reliable suturing materials, the kidney removal gained popularity, and at the same time, became the subject of numerous researches, discoveries, and innovations. Less frequently nephrectomy was performed due to infective renal diseases, whereas the number of patients operated on due to complicated renal lithiasis and renal tumors increased.

In 1945, Ernest K Landsteiner performed the first temporary kidney transplant in Peter Bent Brigham Hospital in Boston. The organ collected from a deceased donor was transplanted to a young pregnant woman with acute renal insufficiency in the course of gestosis.[17] Nine years later, Joseph E. Murray made the first successful transplantation of the kidney collected from a live donor. Transplantation was performed between twins, and the transplanted kidney functioned for nine months.[18]

Evolution of indications for nephrectomy gained considerable pace during the seventies. Since then, we can observe constant growth of morbidity rate of renal cancer, probably related with a change in biology of the tumor. Simultaneously, the number of renal transplantations increases, including collections from living organ donors. What is more, as far as renal lithiasis treatment is concerned, endoscopic methods have finally superseded classical surgery.

## NEPHRON SPARING SURGERIES

The first nephron sparing surgeries were performed a dozen years or more after the first total nephrectomies. In 1884, Spencer Wells accidentally removed the third part of the kidney while performing surgical removal of perirenal fibroadenoma.[19] In 1890, Vincenz Czerny performed the first scheduled operation of partial nephrectomy in a patient with angiosarcoma.[20] What is interesting is the fact that the operation was performed in the same clinic where 21 years earlier Simon had performed the first nephrectomy.

Between 1879 and 1900, intensive studies on safety related with removing a part of the kidney were conducted. Tillman, Tuffier, Bardenheuer, Paoli, and many other researchers made attempts to find the answer for questions related with renal function, compensating mechanisms, and the minimal amount of the kidney essential for the patient to survive.[21] The initial enthusiasm associated with nephron sparing procedures restrained frequent complications following these types of surgeries. Fear of urologists concerning massive bleeding during or after the operation and urinary fistulas, next to poor outcomes of oncological treatment significantly reduced the popularity of partial nephrectomy. Finally, during the first half of the 20th century, nephron sparing operations were mainly reserved only for selected patients, treated due to non-neoplastic renal diseases, including cysts, limited hydronephrosis, and fistulas.

Researches by Albert Goldstein and Benjamin S. Abeshouse (1937) as well as Carl Semb (1950) and Andre Dufour (1951) contributed to increased interest-related nephron sparing operations. These surgeons included an overall number of 321 procedures of partial kidney removal in their analyses. Results of their tests proved that these operations are not related with increased risk of bleeding or urinary fistulas. Goldstein and Abeshouse concluded that small tumors and tumors of moderate size situated at one of the poles of the kidney may be removed by partial resection. Nevertheless, the researchers reserved that this type of action is contraindicated in patients with healthy second kidney.[22] For many years, despite encouraging results of selected studies, partial nephrectomy was not

recommended due to doubtful oncological purity and technical drawback. Patients with one kidney, renal insufficiency, or with both kidneys being sick constituted an exception.

In 1963, urologists focused on researches by Charles Robson from University of Toronto.[23] Robson proved significant improvement in ten-year survival in 88 patients suffering from renal cancer who underwent radical procedure. Due to good outcomes of treatment, radical nephrectomy became a standard of proceedings in patients with renal tumors, delaying the issue of nephron sparing procedures for the next several years.

During the 70s, nephron sparing surgery slowly gained new supporters. Studies by Eugene Poutasse on technique related with partial kidney resection with consideration of segmental vascularization and researches by Kerr and Klotz on renal hypothermia enabling to prolong the time of operation without the fear of ischemia or excessive bleeding were of considerable significance for these changes. In the beginning of the eighties, urologists could take advantage of certain methods related with partial renal resection and renal reconstruction as well as humble experience. On the other hand, the improvement and increase of accessibility of the kidney imaging methods caused significant increase in the number of detected small, asymptomatic renal tumors.

Licht and Novick published the first study on partial nephrectomy on a large group of patients in 1993. During observation lasting for three years on 241 patients with healthy second kidney, only 2 cases of local recurrence and 95% survival were reported.[24] Herr and Fergany independently published similar results of treatment within a longer period of observation.[25, 26] During the last years of the 20$^{th}$ century, nephron sparing procedures gained wide acceptance as a method of treatment for patients with small, peripherally located renal tumors.

Following years strengthened the position of partial nephrectomies. Indications for the surgery were expanded with tumors located within the core of renal medulla and tumors reaching up to 7 cm. According to Herr, the significant growth in the number of executed nephron sparing surgeries may be explained with the fact that the majority of currently detected renal tumors have a diameter of about 4 cm, benign character, or beneficial biology, and global renal function is better in patients with two kidneys.[5]

## VIDEOSCOPIC NEPHRECTOMY

During the first years when laparoscopy was present in surgery, performing nephrectomy with laparoscopic method seemed impossible. Size of the kidney stood as the main obstacle, as they excluded the possibility to remove it from the abdominal cavity through port or by means of mini-laparotomic incision. The problem was solved with construction of non-permeable, strong sac (Lapsac) and morcellator. In 1991, American Ralph Clayman from Washington University School of Medicine in St. Louis, taking advantage of laparoscopic method, preparated a kidney and then placed it inside the sac and minced it with the help of morcellator. Thereafter, the kidney could have been removed from peritoneal cavity through an 11-mm incision.[27]

The volume of the retroperitoneal space was the initial obstacle on the route to endoscopic kidney removal from lumbar access. Operating within this cavity with working tools was dangerous, and sometimes also impossible. In 1992, Durga Gaur from Department of Urology in Bombay Hospital conquered these hardships. Thanks to using a balloon of simple construction, he enlarged the working cavity and removed the kidney with endoscopic method from retroperitoneal access (retroperitoneoscopy).[28,29]

Reports by Clayman and Gaur started a still ongoing discussion concerning indications, difficulties, and outcomes of the kidney removal surgery performed with the help of the above-mentioned means. Analyses reveal predominance of laparoscopic and retroperitoneoscopic techniques over open surgery. When compared with classical surgeries, minimally invasive operations have no influence on the result of oncological treatment and do not increase the risk of surgical complications. They are connected with lesser blood loss, smaller requirement for

analgesic drugs during postoperative period, and shortening the period of hospitalization and the time essential to return to full vital activity. Among the disadvantages of video surgeries, one can enumerate factors that are less significant as far as therapy is concerned, namely costs, technical difficulty of the procedure, and the time it lasts until operators gain experience.

Discussion on comparing laparoscopic operations with retroperitoneoscopic surgery evokes numerous emotions among researchers. Retroperitoneal access found its initial usage in operating small kidneys or removing lesions located on its posterior surface. During the following years, the list of contraindications related with such operation decreased. Recently, retroperitoneoscopic nephrectomy has been definitely advised against only in cases of large kidneys and advanced neoplastic process.[30] Throughout recent years, many urologists took the effort to compare operations from the retroperitoneal and transperitoneal access. Presented results do not show the preponderance of any of these methods, as in both methods, we can observe similar outcomes of treatment and comparable technical difficulties.

Analyzing the history of laparoscopic kidney removal surgery, one cannot forget to mention the use of this technique in collecting the organ for transplantation. In 1995, 41 years after the first open living donor nephrectomy, Lloyd E. Ratner from Johns Hopkins University School of Medicine, Baltimore, executed a similar procedure with laparoscopic method.[31] Pioneer surgery performed on a human being was preceded with experiences on swine models, and results of these studies were published by Gill a year before (Table 2).[32]

**Table 2.** The most important dates in the history of renal surgeries.

| | |
|---|---|
| 1869 | retroperitoneal nephrectomy, Gustav Simon (Heidelberg) |
| 1878 | transperitoneal nephrecotmy, Emil Kocher (Bern) |
| 1890 | partial nephrectomy, Vincezn Czerny (Heidelberg) |
| 1913 | removal of neoplastic thrombus from inferior caval vein, Atle Berg (Oslo) |
| 1954 | living donor nephrectomy, Joseph Murray (Boston) |
| 1990 | laparoscopic nephrectomy, Ralph Clayman (St. Louis) |

## HAND-ASSISTED LAPAROSCOPIC NEPHRECTOMY

Bearing in mind the idea of connecting minimally invasive surgery with potential provided by classical surgery, a technique of hand-assisted laparoscopy was elaborated. In 1997, Stephen Y. Nakada from University of Wisconsin Medical School in Madison described the first nephrectomy within this modification (hand-assisted laparoscopic nephrectomy–HALN).[33] Introducing the hand into the operating field through laparotomy enables palpable evaluation and removal of the whole kidney, and what is more, HALN is characterized by smaller degree of difficulty in comparison with traditional laparoscopic surgery.

Studies comparing HALN with open nephrectomy reveal advantages of minimally invasive operations in relation to HALN, proving its superiority. Less unequivocal conclusions may be drawn from tests comparing HALN with traditional laparoscopic nephrectomy. These procedures are characterized by parallel parameters related with the course of the operation (time of operation, blood loss, oncological radicalness in case of oncological surgeries, and time of warm ischemia in case of the kidney collection) and postoperative period (pain ailments, time of introducing complete diet, and period of hospitalization). Hand-assisted laparoscopic surgeries are less beneficial as far as the economic aspect is concerned.

Author of laparoscopic nephrectomy is one of the enthusiasts supporting HALN. During annual congress of American Urological Association held in 2000, when Clayman commented the HAL technique, admitted that ‘One hand is worth more than thousand trocars’.

## ROBOTIC-ASSISTED NEPHRECTOMY

Robotic-assisted laparoscopic nephrectomy (RALN) is worth mentioning. Introduction of robotic assistants was proposed to increase the precision of movements within the operating field and was related with economic intentions. The assumption was to reduce the number of members within the operating team to minimum. Usually, the procedure is performed by a surgeon

with assistance of one or two robots.

First relations on experimental usage of this method in animals date back to 1994. Initially, robotic assistants were controlled by an experienced urologist present in the operating theater.[34] In 1995, the first 4 nephrectomies performed in people with assistance of two robots, of which one controlled the camera and was controlled with foot pedal and the second one was the 'hook robot' and was controlled with a hand, were described. Authors of the first publication emphasized that procedures performed with robotic assistance are characterized by safety and time of operation similar to typical laparoscopic operations. They also indicated that in case of serious peri-operative complications, human assist is inevitable.[35]

Simultaneous usage of achievements in tele-medicine and robots allowed to perform the first 'distant' surgery, without presence of the surgeon in the operating theater. In 2000, this method was used in an experimental swine kidney removal surgery, which was performed with three robots.[36] Similar procedure was successfully performed a year later in a human being.[37]

Until today, there were a relatively small number of studies comparing RALN with standard laparoscopic operation, hand-assisted laparoscopic surgery in literature. Majority of studies prove lack of advantages related with the use of robots, the surgery lasts longer and obtained outcomes are similar. Selected authors emphasize the value of RALN in perfecting operating techniques by urologists with moderate experience in laparoscopy. During the last months, we could observe publication of studies on results of robotic-assisted partial and living donor nephrectomies. In case of these procedures, urologists frequently indicate the problem concerning the reliable treatment of the kidney peduncle.[38-40] Towards the lack of studies covering large groups of patients undergoing RALN, the economic aspect has not yet been finally evaluated.

## LAPARO-ENDOSCOPIC SINGLE-SITE SURGERY

Laparo-endoscopic single-site surgery modification lies in the use of one multichannel port and curved endoscopic tools. Since 2008, the literature has provided single reports on laparoscopic nephrectomy performed with means of one port. The cosmetic effect is the obvious advantage of the laparo-endoscopic single-site surgery.

Results of previous examinations are promising. Most of the authors consider them safe and practicable.[41] Usually, operators place the port in the navel, which intensified the positive cosmetic outcome of the operation. What is worth mentioning is the fact that the number of previously performed laparoscopic nephrectomies in modification with the use of single port is still insignificant. Hence, finally, this method should be considered as an experimental method, which still does not have a certain place in history of renal surgery.

## NATURAL ORIFICE TRANSLUMINAL ENDOSCOPIC SURGERY

Natural Orifice Transluminal Endoscopic Surgery technique is currently enumerated among the most advanced minimally invasive techniques in surgery. Natural Orifice Transluminal Endoscopic Surgery takes advantage of operative access through natural body orifices, which allows to reduce the number or even eliminate skin incisions, decrease the pain intensity during postoperative period, and to limit the risk of postoperative hernias. The use of Natural Orifice Transluminal Endoscopic Surgery in selected patients (obese patients, burns, and infections within the skin of the abdomen) may facilitate the conditions of operation and allow using anesthesia other than general anesthesia.

In 2001, the kidney preparated with laparoscopic method was removed from the abdominal cavity through the vagina.[42] This notion inspired a group of physicians, who a year later undertook the attempt to perform the whole operation by means of transvaginal access. Six nephrectomies were performed on swine model. In 5 cases, the surgery was performed with the use of one standard port and in one, it was possible to execute the surgery without additional ports, namely entirely through vagina. The two above-

mentioned modifications of operations lasted on average 210 to 360 minutes.[43] During the following years, the swine model was used to perform the kidney removal surgeries from the access through the stomach, the anus, and the bladder.

The first report on using natural body orifices in order to remove the kidney in human dates back to 2008. Then, the Brazilian team operated a 23-year-old woman with recurring infections of the urinary system resulting from an inactive kidney. The surgery was executed with the use of two standard abdominal ports and transvaginal access. Authors of the publication indicated problems related with the use of flexible endoscopic tools to visualize and maintain intra-abdominal structure.[44] The first reports on the operation performed entirely through transvaginal access were published in 2009.[45]

## CONFLICT OF INTEREST

None declared.

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