Evolution of Precision Surgery: Juntendo Experience

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The innovation of surgery centers on the trifecta: precision, low invasiveness and efficient training. Segmentation of the target organ based on the digital information of CT scan can provide the 3D imaging which enables surgical simulation and navigation. With the introduction of surgical robot, da Vinci, Precision Surgery will be implemented in all surgical procedures.

Key words: Precision medicine, segmentation, 3D imaging, simulation, navigation, da Vinci

The history of surgery dates back thousands of years. Natural history museum in Lausanne, France shows us a drilled skull from around 6,500 BCE. The procedure of drilling a skull is called trephination. Surprisingly, the hole was not made postmortem, but was made in life for the purpose of medical treatment or religious rituals. Furthermore, the rounded edge of such holes indicates that individuals who underwent trephination survived fairly long after the operation.

From the dawn of history until 18 century, lithotomy for removal of bladder stones should be enumerated as one of the most progressive and major operations done by our great ancestors (Figure-1). Bladder stones triggered by urinary infection caused hematuria, pain and fever, which could have been lethal in the ancient era. The removal of bladder stone, cystolithotomy, was a risky procedure in which the stone was pressed down into the perineum by the fingers in the rectum until it could be reached from the urethra, then, the stone was removed from the incision at perineum \(^1\). As a matter of fact, Hippocratic Oath states that lithotomy must be performed by practitioners, specialists in this art. The Hippocratic Oath actually defined, identified and legitimized urology as the first medical specialty \(^2\) (Figure-2).
In 16–17th century, cystolithotomy was still very dangerous operation, and most patients died immediately after surgery because of massive hemorrhage. Until the advent of endoscope, forceps was inserted into the bladder, and surgeons searched for stone in a rather blind manner until 20th centuries (Figure-3). Although cystolithotomy was necessary to alleviate patients’ symptoms and cure the disease, the procedure has been incorrect, harmful and invasive to the patients, and hard to teach successors.

The innovation of surgery centers on the trifecta; precision, low invasiveness and efficient training. To achieve precision in surgeries, simulation and navigational guidance for the surgery are prerequisite. One of the key features of less-invasive surgeries is the circumvention of laparotomy and muscle incision. Furthermore, transmission of surgical techniques to the surgeons of next-generation is pivotal for the efficiency and conserva-

I will not use the knife, not even on sufferers from stone, but will withdraw in favour of such men as are engaged in this work.

Figure-2 The Hippocratic Oath defined urology as the first medical speciality (Adams F: The Genuine Works of Hippocrates, Translated from the Greek, 1939).

Figure-3 Transurethral litholapaxy in 20th century. This procedure often ended up with incomplete removal of bladder stone, bleeding, and casing patient intractable pain. Moreover this procedure was hard to teach since it was performed in a blind manner.
tion of limited medical resources.

In 2015, President Obama of the United States launched precision medicine initiative, which is a health care tailored to each individual based on the genomic information (https://www.whitehouse.gov/precision-medicine). It has started to take effect in the field of cancer chemotherapy therapy by selecting patients to whom certain medication is presumably effective. Until now, empiric therapy progressed to standardized therapy based on evidence-based medicine. Precision medicine further improves the present standardized medicine to provide the most effective care to individuals by integrating genes, lifestyle and environment (Figure-4). This analogy is applicable to surgeries as well. Certification of surgeon and clinical guidelines have secured the safety and standardization of surgery. Now surgical simulation and navigational

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**Figure-5** "Precision Surgery“ prerequisites simulation and navigation

**Figure-6** Segmented 3D imaging of renal anatomical structures
Figure 7  Robotic-assisted surgery "daVinci"

Figure 8  2D imaging of left renal tumor
Arrow: a tumor

Figure 9  3D model of a kidney with tumor produced by a 3D printer

Figure 10  Precision Surgery in partial nephrectomy
Good correlation was achieved between planned resected volume and actual one of the surgical specimen.
guidance enable precision surgery based on individual anatomical differences (Figure-5).

Evolution of surgical navigation is greatly attributable to progression of CT scan techniques. CT scan provides not only two-dimensional images (Figure-6), but also integrated three-dimensional images by utilizing its digital information. Three-dimensional model with segmentation enabled both patients and doctors to intuitively recognize diseases (Figure-7). An Operational robot, da Vinci, possesses innovational trifecta, precision, low invasiveness and efficient training, as well as facilitating precision surgery (Figure-8).

We utilized 3D printer to generate 3D model of organs in an effort to complement a flaw of robotic surgeries, which is a lack of tactile sensation (Figure-9). During actual operations, we can put

Figure-11  Comparison of simulation and surgical outcome in partial nephrectomy
Left: 3D imaging for the partial nephrectomy. Right: Actual surgical specimen.

Figure-12  CT volumetry by 3D segmentation
Surgically resected volume can be planned and estimated beforehand. CT volumetry can estimated the loss of GFR by the resection of renal parenchyma.

Figure-13  Correlation between predicted postoperative eGFR and observed postoperative eGFR
3D images on the monitor of surgeon’s console of da Vinci for operational navigations. For example, it is hard to resect a tumor adjacent to hilum of kidney or a tumor located inside the kidney. In these situation, nephrectomy is a standard surgery even though the size of the tumor is small. Thanks to 3D imaging, we can accurately grasp the locations of a tumor, vessels and urinary tract. We now safely and precisely perform the resection of a tumor in the kidney even located in renal hilum in Juntendo Hospital\(^4\). We report that good correlation was achieved between planned resected volume and actual one of the surgical specimen (Figure-10, 11). Furthermore, we can predict the residual renal function (estimated glomerular filtration ratio: eGFR) after partial nephrectomy by using combination of clinical indices with CT volumetry\(^5\) (Figure-12, 13).

**Conclusion**

Empiric therapy evolved to evidence-based medicine, which further progressed to precision medicine based on genomic information. Although surgery itself is personalized medicine by its nature, da Vinci and 3D imaging facilitates precision surgery. In Juntendo Hospital we will establish precision surgery to maximize the benefits of patients.

**Reference**