

Supplementary Table 1: Reported cases of laparoscopic S2 monosegment liver graft procurement

| Year | First author | Donor (age, gender) | <i>In situ</i> splitting | ICG imaging | Glissonean approach | Operating time (min) | Blood loss (mL) | GV (g) | Post-operative complications |
|------|-----------------------------------|---------------------|--------------------------|-------------|---------------------|----------------------|-----------------|--------|------------------------------|
| 2018 | Hong <i>et al.</i> ^[4] | 43, female | Yes | Yes | No | 320 | - | 167.0 | No |
| 2020 | Li <i>et al.</i> ^[5] | 35, male | Yes | Yes | No | 200 | - | 225.2 | No |
| 2021 | Our case | 24, female | Yes | Yes | Yes | 332 | 34 | 141.0 | No |

ICG: Indocyanine green, GV: Graft volume

Single-port laparoscopic appendectomy for perforated appendicitis using ArtiSential[®] wristed articulated instrument

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Abstract

Single-port laparoscopic appendectomy (SPLA) was firstly introduced in 1998 and has been suggested potential advantages including better cosmetic outcome, less post-operative pain and avoidance of possible haemorrhagic complications from injuring epigastric vessels. However, single-port laparoscopic approach using conventional straight instruments may lead to internal and external conflicts and ergonomic discomfort, and new laparoscopic articulating instruments were developed to overcome these limitations of straight instruments. The ArtiSential[®] (LIVSMED Inc., Republic of Korea) is an 8-mm diameter pistol-handle instrument that has complete articulating function like human wrist and intuitive controllability. We present a technical report of SPLA for perforated appendicitis using ArtiSential[®] wristed articulated instrument. A 78-year-old female with a body mass index of 23.5 was referred to our emergency room with right lower quadrant abdominal pain. Abdominal computed tomography scan showed a distended tubular structure in the right lower quadrant (1.2 cm in diameter) with periappendiceal fluid collection. The patient's clinical presentation was highly indicative of perforated acute appendicitis. We performed SPLA with ArtiSential[®] grasper with the left hand, and this instrument helped us to allow greater manoeuvrability and dexterity with double triangulation technique. The total operation time was 40 min, and the patient was discharged without complications on the 1st day after surgery.

Keywords: Appendectomy, laparoscopy, natural orifice endoscopic surgery

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INTRODUCTION

Laparoscopic appendectomy was first described by Semm in 1983, and this approach was quickly accepted as a suitable treatment option for uncomplicated appendicitis.^[1] Previous studies have reported that laparoscopic appendectomy has some advantages, including fewer days to return to regular

diet, shorter duration of parenteral analgesics, requiring lesser doses of morphine equivalent parenteral opioids, and shorter post-operative hospital stay compared to laparotomy.^[2,3]

With the advancement of minimally invasive surgery, minimising surgical trauma and improving cosmetic outcomes have evolved as current topics of active

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discussion, which have led to the development of single-port laparoscopic surgery (SPLS) for the treatment of a variety of conditions including acute appendicitis.^[4-6] As the number of incisions has reduced to one umbilical incision, a single access can translate into less post-operative incision pain, fewer wound complications and improved cosmetic outcomes.

However, single-port laparoscopic approach using conventional straight instruments may lead to internal and external conflicts and ergonomic discomfort, and new laparoscopic articulating instruments were developed to overcome these limitations of straight instruments.^[7] The ArtiSential® (LIVSMED Inc., Republic of Korea) is an 8-mm diameter pistol-handle instrument that has complete articulating function like human wrist and intuitive controllability. Since ArtiSential® was registered as a class I medical device with the Korea Food and Drug Administration in 2019, it has been certified by the US Food and Drug Administration, the European Community Mark (CE) and the Japan Pharmaceuticals and Medical Devices Agency. Herein, we describe our innovative single-port laparoscopic appendectomy (SPLA) technique using the ArtiSential® grasper, which is a wristed articulated instrument.

TECHNIQUE

A 78-year-old female with a body mass index of 23.5 was referred to our emergency room with right lower quadrant abdominal pain. Abdominal computed tomography scan showed a distended tubular structure in the right lower quadrant (1.2 cm in diameter) with periappendiceal fluid collection [Figure 1]. The patient's clinical presentation was highly indicative of perforated acute appendicitis, and we planned to perform SPLA with an ArtiSential® wristed articulated instrument after obtaining the content from the patient [Figure 2 and Video 1]. After everting the base of the umbilical stalk using two penetrating towel clamps placed on either side of the midline, a single 2.0-cm vertical incision was made through the umbilical skin [Figure 3a].

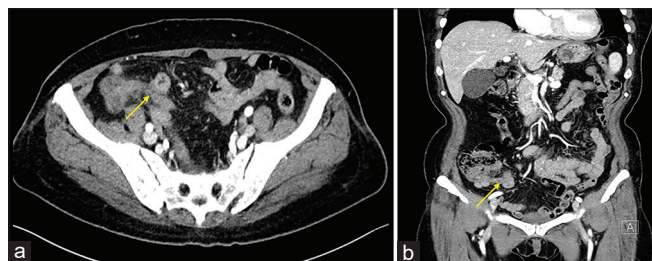


Figure 1: Pre-operative abdominal computed tomography scan of appendicitis with periappendiceal fluid collection. (a) Axial image. (b) Coronal image

A single-port Glove Port® (Nelis Corp., Republic of Korea) was placed in the abdominal cavity through the umbilical incision [Figure 3b]. After laparoscopic exploration, the tip of the appendix was held with an ArtiSential® fenestrated grasper with the left hand, and the mesoappendix was dissected using a Thunderbeat® (Olympus Medical Systems Corp., Tokyo, Japan) with the right hand [Figure 3c and d]. For SPLS with a wristed articulated instrument, we used the ‘double triangulation technique’ for efficient grasping and traction [Figure 4]. To ensure an efficient procedure on the appendiceal base, caecal mobilisation using a monopolar device with the right hand was performed when holding the cecum using a wristed grasper with the left hand. The appendiceal base was ligated by the application of two endo-loops. During this process, articulation of the wristed grasper was useful in entering the loop and grabbing the appendix [Figure 3e]. The appendix was removed through a single port, after which thorough irrigation of the periappendiceal and subhepatic areas with normal saline was performed [Figure 3f]. The skin was closed subcuticular sutures and Dermabond (Ethicon, Johnson and Johnson, Somerville, NJ, USA) [Figure 5]. The total operation time was 40 min, and the patient was discharged without complications on the 1st day after surgery.

DISCUSSION

In multi-port laparoscopic surgery, the ‘triangulation technique’ that connects the target organ and two ports is used to obtain an efficient surgical view, and in SPLS, an ‘inverse triangulation technique’ that implies crossing two straight instruments is used to reduce collisions between the camera and laparoscopic instruments [Figure 5]. To minimise hand collisions and achieve triangulation in SPLS, the surgeon generally crosses the instruments inside the abdomen. This consists of crossing straight laparoscopic instruments at a single port to place the left and right instruments on the right and left sides, respectively. However, this often results in decreased surgical performance and increased fatigue and stress.

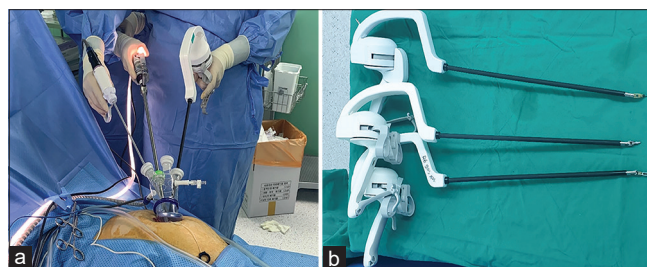


Figure 2: Operative view. (a) Operative setup for single-port laparoscopic appendectomy with the wristed instrument. (b) ArtiSential® articulated instrument, from above: Monopolar spatula, needle holder and fenestrated forceps

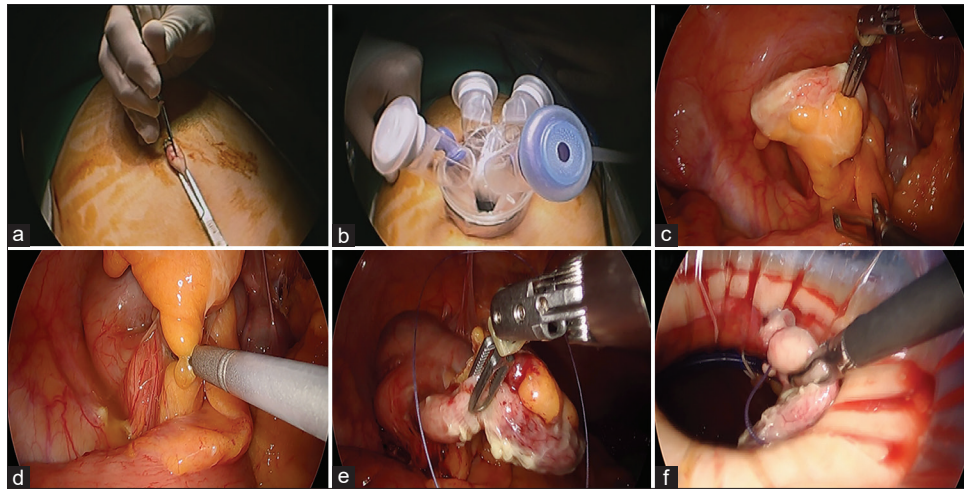


Figure 3: Single-port laparoscopic appendectomy with ArtiSential® articulated instrument. (a) A single 1.2-cm vertical incision was made through the umbilical skin. (b) A multi-channel single port was inserted through the umbilical incision. (c) The appendix tip was held the grasper with the left hand. (d) The mesoappendix was dissected using the Thunderbeat® with the right hand. (e) Double ligation of the appendiceal base was performed using three endo-loops. (f) Resected appendix as extracted thou

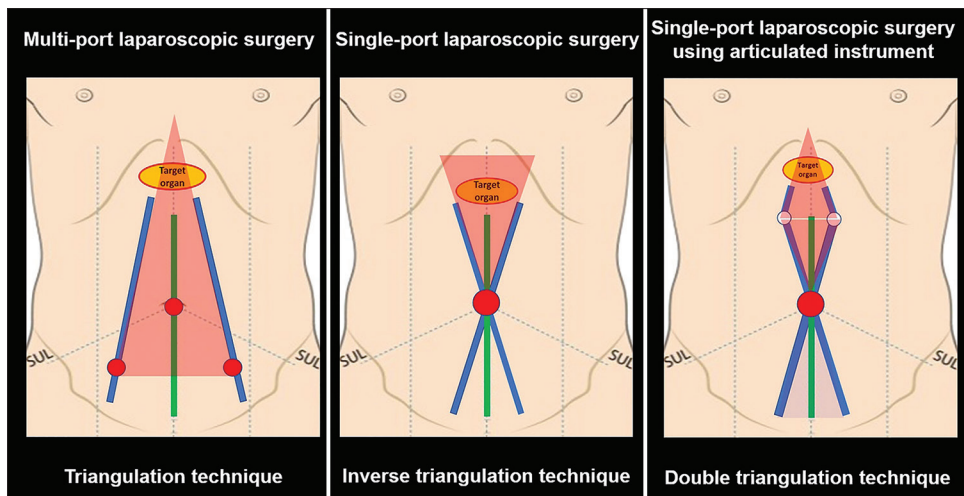


Figure 4: Positioning of the surgical instruments according to various kinds of minimally invasive approaches



Figure 5: Post-operative scar view

The single-port surgical instrumentation package for the da Vinci Single-Site® system (Intuitive Surgical, Sunnyvale, CA, USA) was specially designed to overcome the limitations of SPLS.^[8] In addition, the da Vinci SP platform, specifically designed for single-port surgery, is being developed for various diseases. When inserted directly into the abdominal cavity through a single incision, the highly flexible robotic arm offers high dexterity, especially in transanal, transoral and transabdominal surgery.^[9-11] However, a significant drawback of these robotic platforms is the high cost of robotic surgery, which cannot be afforded by all hospitals, especially for benign diseases, including appendiceal diseases. The da Vinci Surgical System costs upward of \$20,000, whereas an ArtiSential® instrument costs roughly \$600. ArtiSential® instruments are more cost-effective than

a robotic system; however, the cost of a new ArtiSential® instrument is expensive compared to that of reusable straight laparoscopic instruments.

Several laparoscopic joint instruments have been introduced as alternatives to robotic systems for minimally invasive surgeries.^[7] This tool has several properties that allow it to be articulated or bent into a curved arc. However, we consider the da Vinci robotic system and ArtiSential® instruments to be a 'wristed' instrument that is similar to a human wrist, and not simply an 'articulated' instrument for minimally invasive surgery. We can perform SPLS for appendectomy using an ArtiSential® grasper with the left hand as this instrument helped us to achieve greater manoeuvrability and dexterity using the 'double triangulation technique' [Figure 4]. Surgeons can use the benefits of articulation at a much lower cost and feel force feedback, which makes the operation safer. It is also possible to perform surgery directly on the side of the patient, which is an advantage as it allows the patient to be treated quickly in an emergency, compared to a robotic platform. Using this instrument, excessive traction, which often occurs in SPLS, can be avoided, and caecal mobilisation and ligation of the appendiceal base using an endo-loop can be efficiently and safely performed. However, the disadvantage of this instrument is that it is heavier than conventional abdominal instruments and requires greater force to operate the fingers, which makes it difficult to use for long periods of time. In addition, due to the large volume of the general abdominal cavity, collisions of the instruments may occur.

Based on our brief technical report, we anticipate that this instrument can be used as a tool to secure additional movement flexibility in SPLS or to treat diseases, such as benign diseases, where it is difficult to apply to robotic systems owing to their high cost. In addition, we believe that these instruments can be helpful in performing SPLS even for inexperienced surgeons if they become familiar with the ArtiSential® instruments.

Declaration of patient consent

The authors certify that they have obtained all appropriate

patient consent forms. In the form, the patient has given her consent for her images and other clinical information to be reported in the journal. The patient understands that her name and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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