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동물 모델에서 새로운 관절식 복강경 기구를 이용한 신장 수술

Renal surgery using New Articulating Laparoscopic Instruments in an animal model

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이 논문을 의학박사 학위 논문으로 제출함

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Abstract

Purpose: We conducted an evaluation of the performance of a novel multi-degree-of-freedom articulating laparoscopic devices, ArtiSential, and compared it with that of a straight-shaped devices, the da Vinci surgical system, in the steps of renal surgery in an animal model.

Materials and Methods: Nine female Yorkshire pigs were evenly distributed into three groups, and objective and subjective parameters were assessed and compared across the groups at each surgical step.

Results: Significantly shorter mean operation time for renal pedicle clamping and ureter dissection were observed in the ArtiSential group compared to the robotic group (1.4 min vs. 5.5 min, $p < 0.01$; 7.2 min vs. 11.3 min, $p = 0.01$, respectively). However, the ArtiSential group demonstrated a significantly longer mean operation time for bladder repair compared to both the straight-shaped and robotic groups (16.0 min vs. 9.4 min and 16.0 min vs. 5.9 min, $p < 0.01$ for both comparisons). No statistically significant differences were detected among the groups with respect to either intraoperative complications or blood loss. Compared to the robotic system, the ArtiSential device was determined to be less useable for bladder repair ($p < 0.01$) and renorrhaphy ($p = 0.02$). The ArtiSential group exhibited less accuracy than the robotic group in step of renorrhaphy, bladder repair and tumor resection. During renal pedicle ligation, ureter dissection, bladder cuff excision, renorrhaphy, and bladder repair, the surgeon experienced greater wrist stress but less back stress in the ArtiSential group compared to the robotic group.

Conclusions: For the majority of surgical steps, the ArtiSential instrument demonstrated comparable performance to both robotic and straight-shaped instruments. The potential advantages of ArtiSential could be further optimized through the development of specialized surgical techniques.

Keywords: Articulating; Laparoscopy; Robotics; Kidney

CONTENTS

List of Tables

List of Figures

Introduction

The favorable perioperative and oncologic outcomes associated with laparoscopic surgery have led to its rapid displacement of open surgery as the preferred method in urologic surgical procedures, leading to the development of specialized laparoscopic instruments. Despite the rise of laparoscopic surgery, previous studies had suggested a positive correlation between prolonged static postures adopted by surgeons during the execution of laparoscopic procedures and an increased risk of musculoskeletal stress.[1] Nowadays, robotic surgery has gained increasing popularity as an ergonomically superior alternative to laparoscopic surgery, with enhanced visualization and tissue manipulation facilitated by freedom of movements of the surgical instruments.[2] Porpiglia et al. reported have comparable or superior outcomes from robotic surgery in comparison to laparoscopic surgery.[3] Despite its advantages, robotic surgery does have certain limitations. Specifically, the utilization of the robotic platform necessitates specialized devices and environmental considerations, precludes haptic feedback, and carries a higher cost relative to alternative surgical approaches.[2,4,5]

A novel multi degree-of-freedom articulating laparoscopic instrument known as ArtiSential (LIVSMED, Seongnam, Republic of Korea) has recently been introduced in renal surgery. (Figure 1) This instrument offers the benefit of wrist-like movement similar to robotic arms, thereby addressing the limitations associated with straight-shaped laparoscopic devices.[6]

ArtiSential may overcomes the limitations of conventional instruments by allowing free movement of the joint over a 360° range, similar to that of robotic arms. However, only a limited number of studies have reported on the efficacy of this laparoscopic articulating instruments in specific surgical fields.[7,8] A dearth of studies exists that assess the safety, usability, accuracy, and the musculoskeletal stress imposed on surgeons with the use of this instrument in the urology field.[6] As clinical application of the ArtiSential instruments in renal surgery is still in its novel stages, we employed an animal model to compare the surgical implications using these instruments with those of the robotic systems or straight-shaped laparoscopic instrument.

Figure 1. Illustration of a novel multi degree-of-freedom articulating laparoscopic instrument (ArtiSential)

Materials and Methods

Study design and Animal preparation

The protocols for performing animal experiments were approved by the Institutional Animal Care and Use Committee of Asan Medical Center. Nine female Yorkshire pigs aged 4 weeks were acclimatized to the large animal facility for two days prior to surgery. The pigs were fed a low residue diet for 2 days before the surgery. Six pigs weighing 32.7 to 37.7 kg were equally divided into 3 groups (six kidneys per group): Robotic, ArtiSential, and straight-shaped instrument groups. Prior to anesthesia, each pigs received a pre-medication consisting of an intramuscular injection of alfaxane (1 mg/kg) combined with azaperone (4 mg/kg) and xylazine HCl (1.2 mg/kg). The procedures were carried out under general anesthesia using 2-3% isoflurane. Sterile instruments were prepared for renal surgery. Vital signs (blood pressure, heart rate, oxygen saturation, and respiration rate) were monitored during general anesthesia. All pigs were euthanized after all procedures.

Animal position and Portal location

We adopted the same method as that used in our previous study to position the port placements and stabilize the posture of the pig. [9] For left renal surgery, pigs were situated in a right lateral decubitus position and meticulously surgical draped. Pneumoperitoneum was established using a Veress needle to introduce carbon dioxide into the peritoneal cavity. To perform surgery on right kidney, the same pig was repositioned onto its the left lateral decubitus, and then pneumoperitoneum was established using same manner.

In each stage of the surgical procedure, four ports were typically utilized. When performing left renal surgery, a 0.8-1 cm camera port was situated 4 cm laterally to the left of the midline and 10 cm cranial to the umbilicus. The working port (also 0.8-1 cm) was positioned 15 cm from the bony prominence of the external ilium, while maintaining a 13 cm distance from the last rib. The backhand port (0.8-1 cm) was located 15 cm from the angle of the last costovertebral joint. Finally, an additional port (0.5 cm) was placed approximately 18 cm laterally to the camera port. For right renal surgery, the placement of the ports was placed symmetrically.

Figure 2A illustrates the pig's position and port placement for straight-shaped laparoscopic surgery, while Figure 2B shows the preparation of surgery for ArtiSential laparoscopic surgery.

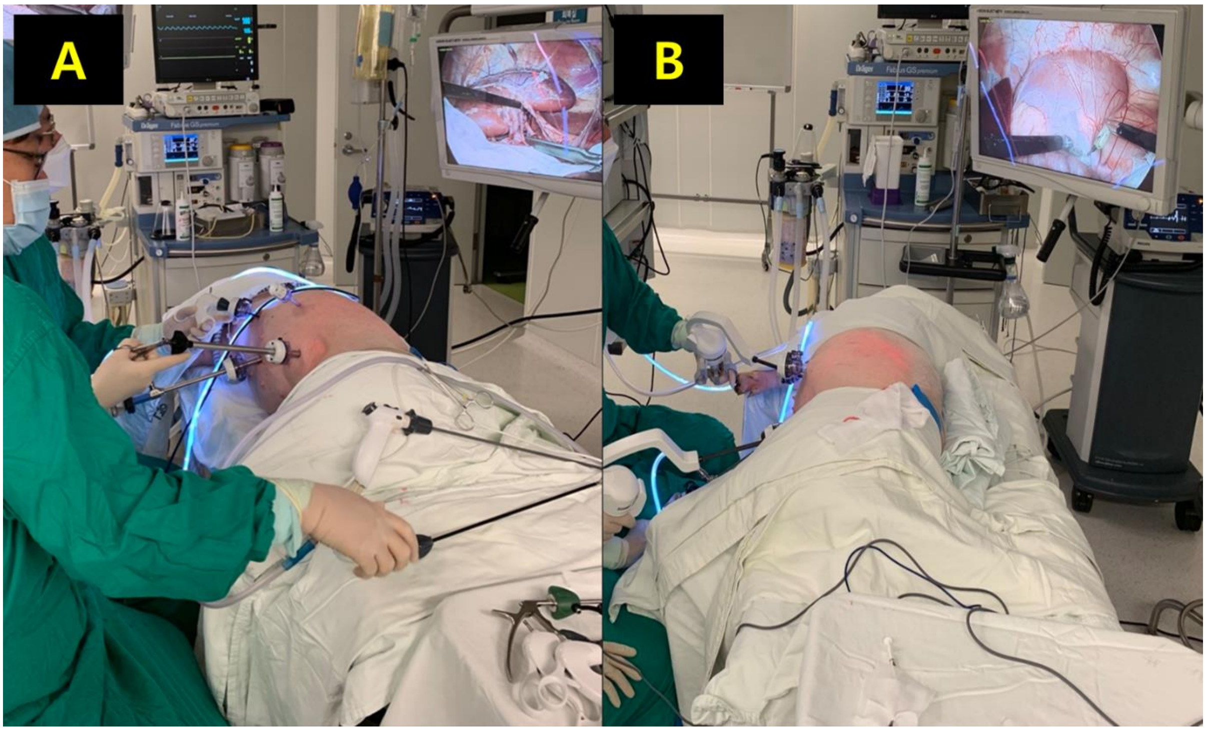

Figure 2. Illustration of animal position and port placement: (A) Straight-shaped group (B) ArtiSential group

Surgical procedure

A single surgeon (DY) performed all surgical procedures. As categorized in our prior preclinical investigation, representative renal surgeries, which included nephrectomy, partial nephrectomy, and nephroureterectomy with bladder cuff excision, were subdivided into 10 detailed steps.[9] (Table 1)

First, in the step of kidney mobilization, the retroperitoneum was incised at the hilum to expose the ventral aspect of the renal vasculature. Second, the renal pedicle dissection has prepared by dissecting the main renal vessels while removing all perivascular tissue to avoid interference with subsequent ligation. Third, bulldog clamps were used to sequentially clamp the main renal artery and vein during renal pedicle clamping. Fourth, a $1 \times 1\text{-cm}^2$ kidney block of the lateral portion in the middle pole was resected to perform tumor resection. Fifth, we sutured the dissected surface of kidney with absorbable 3-0 suture materials using a sliding-clip technique in renorrhaphy. After de-clamping the renal pedicle, the surgeon inspected the renorrhaphy site and performed meticulous bleeding controls by applying additional sutures. Sixth, the main renal vessel was ligated with medium-sized Hem-o-lok clips. Seventh, the ipsilateral ureter was dissected to the entrance of the bladder during ureter dissection. Eighth, ureter was ligated with Hem-o-lok clip and excision. Ninth, a 4-French feeding tube was inserted into the remnant ureter, and the tip of the tube was placed in the bladder for bladder cuff excision, which included the intra-vesical ureteral orifice. Finally, bladder repair was performed in a water-tight manner with absorbable 3-0 sutures, followed by a bladder leak test through a urethral catheter.

Table 1. The detailed 10 surgical steps in renal surgery

	Radical nephrectomy	Partial nephrectomy	Nephroureterectomy with bladder cuffing
Kidney mobilization	Yes	Yes	Yes
Renal pedicle dissection	Yes	Yes	Yes
Renal pedicle clamping	No	Yes	No
Tumor resection	No	Yes	No
Renorrhaphy	No	Yes	No
Renal pedicle ligation	Yes	No	Yes
Ureter dissection	Yes	No	Yes
Ureter ligation	Yes	No	No
Bladder cuff excision	No	No	Yes
Bladder repair	No	No	Yes

Surgical device detailing for each group

As utilized in our prior preclinical investigation, [9] in the robotic group, the surgeon exclusively utilized robotic instruments, including monopolar curved scissors, Maryland bipolar forceps, ProGrasp forceps, clip applier, and two needle drivers (namely Mega SutureCut). In the ArtiSential group employed multi-degree-of-freedom articulating instruments, such as monopolar spatula, Maryland dissector, clip applier, and one needle holder, while the straight-shaped instrument group relied on conventional laparoscopic instruments, such as Monopolar hook, scissor, clip applier, and one needle holder. Due to the unavailability of certain ArtiSential instruments, the surgeon in the ArtiSential group resorted to using a conventional laparoscopic scissor for tumor resection and laparoscopic bulldog clip applying forceps (Aesculap, Tuttlingen, Germany) for renal pedicle clamping. The surgical instruments used for each step are detailed in Table 2.

Table 2. Summary of surgical device in each procedure among three groups

10 surgical steps	Robotic group		ArtiSential group		Straight-shaped group	
	Left hand	Right hand	Left hand	Right hand	Left hand	Right hand
Kidney mobilization	Robotic Maryland bipolar forceps	Robotic Hot Shears™ (monopolar curved scissors)	AritiSential Maryland dissector	ArtiSential monopolar spatula	Laparoscopic dissector forceps	Laparoscopic monopolar hook
Renal pedicle dissection						
Renal pedicle clamping		Robotic ProGrasp™ forceps (Bulldog clamps)		Laparoscopic bulldog clip applying forceps (Aesculap® bulldog Clips)		Laparoscopic bulldog clip applying forceps (Aesculap® bulldog clips)
Tumor resection		Robotic Hot Shears™ (monopolar curved scissors)		Laparoscopic scissors		Laparoscopic scissors
Renorrhaphy	Robotic large needle driver	Robotic Mega SutureCut™ needle driver		ArtiSential needle holder		Laparoscopic needle holder
Renal pedicle ligation	Robotic Maryland bipolar forceps	Robotic medium-large clip applier		ArtiSential medium-large clip applier		Laparoscopic medium-large clip applier
Ureter dissection		Robotic Hot Shears™ (monopolar curved scissors)		ArtiSential monopolar spatula		Laparoscopic monopolar hook
Ureter ligation		Robotic medium-large clip applier		ArtiSential medium-large clip applier		Laparoscopic medium-large clip applier
Bladder cuff excision		Robotic Hot Shears™ (monopolar curved scissors)		ArtiSential monopolar spatula		Laparoscopic monopolar hook
Bladder repair	Robotic large needle driver	Robotic Mega SutureCut™ needle driver		ArtiSential needle holder		Laparoscopic needle holder

Outcome measurements

At each stage of this study, a comparative analysis was performed on three groups with respect to both objective and subjective parameters. The objective parameters comprised the operation time, blood loss, and intraoperative complications. The intraoperative complications were evaluated and graded based on the modified Satava classification system, which is specific to each type of procedure.

The investigation was performed subjective parameters that encompassed the usability of the devices as determined by the single operator, the accuracy of the procedure as appraised by reviewers, and the incidence of musculoskeletal stress reported by the single operator. The accuracy of the procedure was assessed by 8 reviewers who examined recorded videos of each step and assigned a score based on established criteria. The reviewers had an average of 5.6 years (standard deviation 3.6 years) of actual experience after acquiring a urology board certificate and were working at a tertiary hospital when they participated in this study. Each procedure was assessed for its usability and accuracy using a 5-point Likert scale, where a rating of 5 denoted excellent, 4 denoted good, 3 denoted fair, 2 denoted poor, and 1 denoted very poor. We assessed the level of musculoskeletal stress experienced by the surgeon during each joint operation, including the neck, back, hands, wrists, elbows, shoulders, and legs by utilizing a self-made scale. The degree of stress was measured using a 5-point scale, where a rating of 5 indicated no pain, 4 denoted weak pain, 3 denoted moderate pain, 2 denoted moderately strong pain, and 1 denoted extremely strong pain.

Statistical Analysis

Categorical variables were presented as a number (%) and continuous variables were presented as the mean (standard deviation; SD). The comparisons were two-sided and a p-value less than 0.05 was regarded as statistically significant. Variables with skewed distributions were compared between two groups using the Mann-Whitney U test and variables with skewed distributions were compared among three groups using the Kruskal-Wallis test. All statistical analyses were conducted with SPSS® version 24.0.

Results

Comparison of animal data throughout the renal surgery

The nine pigs underwent without need for conversion to open surgery. Renal surgery was performed on three pigs in each group, resulting in a total of six renal units undergoing surgery in each group. The mean (SD) body weight was 35.1 (2.4) kg in the robotic group, 34.1 (0.5) kg in the ArtiSential group, and 33.5 (0.6) kg in the straight-shaped group. The mean (SD) kidney weight was 109.9 (13.1) g in the robotic group, 102.9 (10.5) g in the ArtiSential group, and 93.2 (14.8) g in the straight-shaped group ($p = 0.115$). There was no significant difference among the groups in overall operation time or estimated blood loss.

There were no significant differences in intraoperative complications among the three groups. However, the robotic group had two complications, including one vein injury (grade I) and one intestinal injury (grade II). The ArtiSential group had three complications, which included one kidney parenchymal injury (grade I) and two vascular injuries (grade II). The straight-shaped group had two complications, including one ureteral injury (grade II) and one main arterial injury (grade III), as shown in Table 3.

Table 3. Summary of animals' backgrounds and overall procedures

	Robotic group	ArtiSential group	Straight-shaped group	p-value
Body weight, kg	35.1 ± 2.4	34.1 ± 0.5	33.5 ± 0.6	0.203
Kidney weight, g	109.9 ±13.1	102.9 ±10.5	93.2 ± 14.8	0.115
Operation time, min	63.4 ± 13.7	64.1 ± 4.1	76.9 ± 15.7	0.225
Blood loss, ml	14.4 ± 8.0	14.7 ± 3.5	17.5 ± 18.4	0.881
Intraoperation complication	2	3	2	0.854

Comparison of objective parameters in each surgical step

The ArtiSential group showed significantly shorter mean operation time for renal pedicle clamping and ureter dissection when compared to the robotic group, with times of 1.4 minutes versus 5.5 minutes ($p < 0.01$) and 7.2 minutes versus 11.3 minutes ($p = 0.01$), respectively. The ArtiSential group had a significantly longer mean operation time for bladder repair when compared to both the robotic group and the straight-shaped group, with times of 16.0 minutes versus 5.9 minutes and 16.0 minutes versus 9.4 minutes, respectively ($p < 0.01$ for both comparisons) as shown in Figure 3.

There were no significant differences in blood loss among the three groups in each step of the renal surgery, as shown in Figure 4.

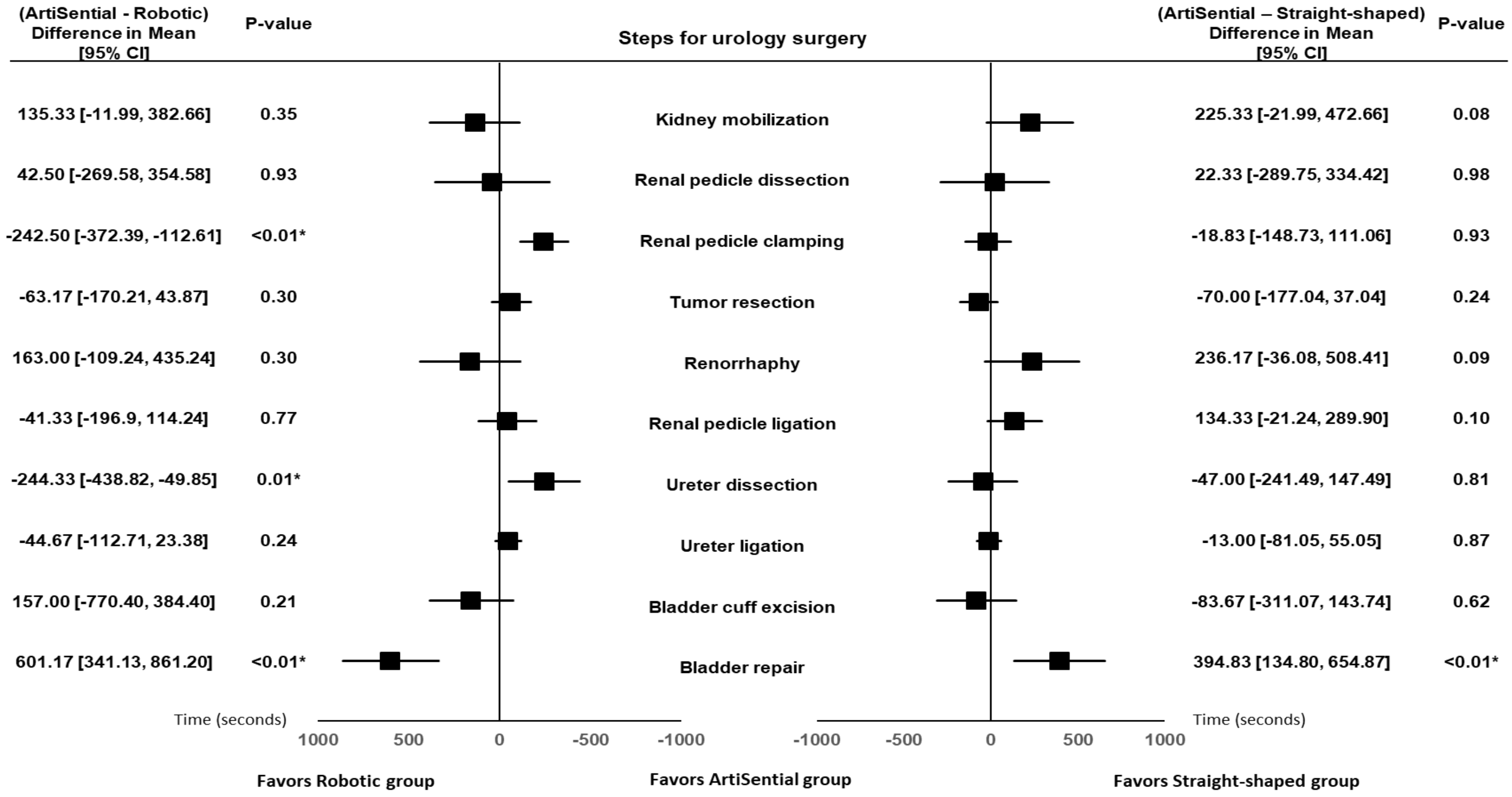

Figure 3. Illustration of a forest plot for difference in mean operation time (seconds) within each group

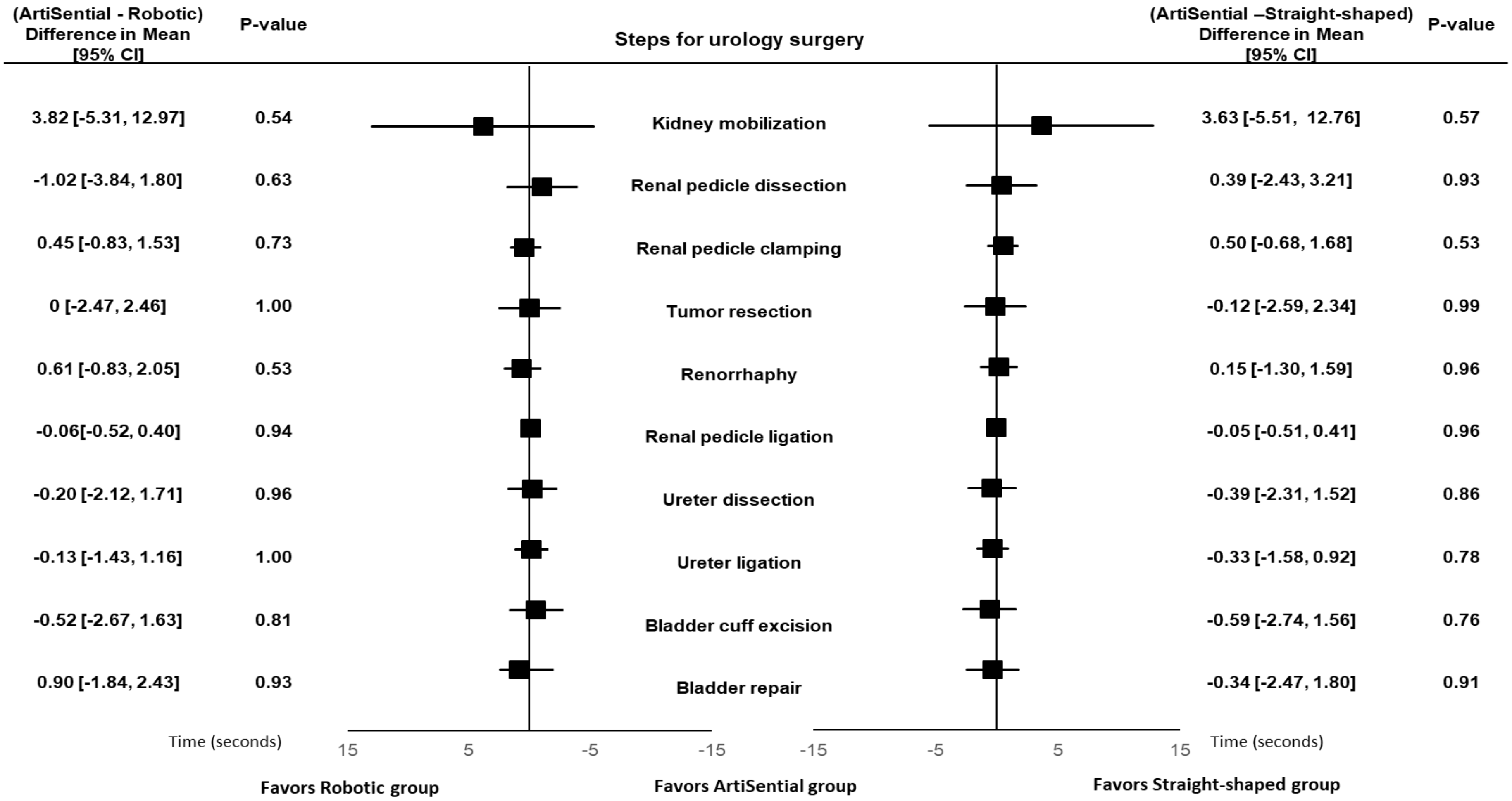

Figure 4. Illustration of a forest plot for difference in blood loss (ml) within each group

Comparison of subjective parameters in each surgical step

The robotic surgical system was significantly more useful than the ArtiSential device in performing renorrhaphy ($p= 0.02$) and bladder repair ($p <0.01$), while no significant differences in usability were observed between the ArtiSential group and the straight-shaped group in any surgical step as shown in Figure 5.

The ArtiSential group demonstrated lower accuracy than the robotic group in tumor resection, renorrhaphy, and bladder repair. But the ArtiSential group demonstrated higher accuracy in bladder cuff excision compared to the straight-shaped group, though lower accuracy in bladder repair as shown in Figure 6.

The ArtiSential group resulted in less hand stress during ureter dissection than the straight-shaped instrument group, as shown in Figure 7. On the other hand, for surgical procedures such as renorrhaphy, renal pedicle ligation, ureter dissection, bladder cuff excision, and bladder repair, the surgeon experienced more discomfort in the wrist in the ArtiSential group than the robotic group, as illustrated in Figure 8. However, the ArtiSential group caused less discomfort in the back than the robotic group, according to Figure 9. There was no significant difference in stress on the surgeon's neck, elbows, shoulders, and legs among the three groups, as demonstrated in Figure 10, 11, 12,13.

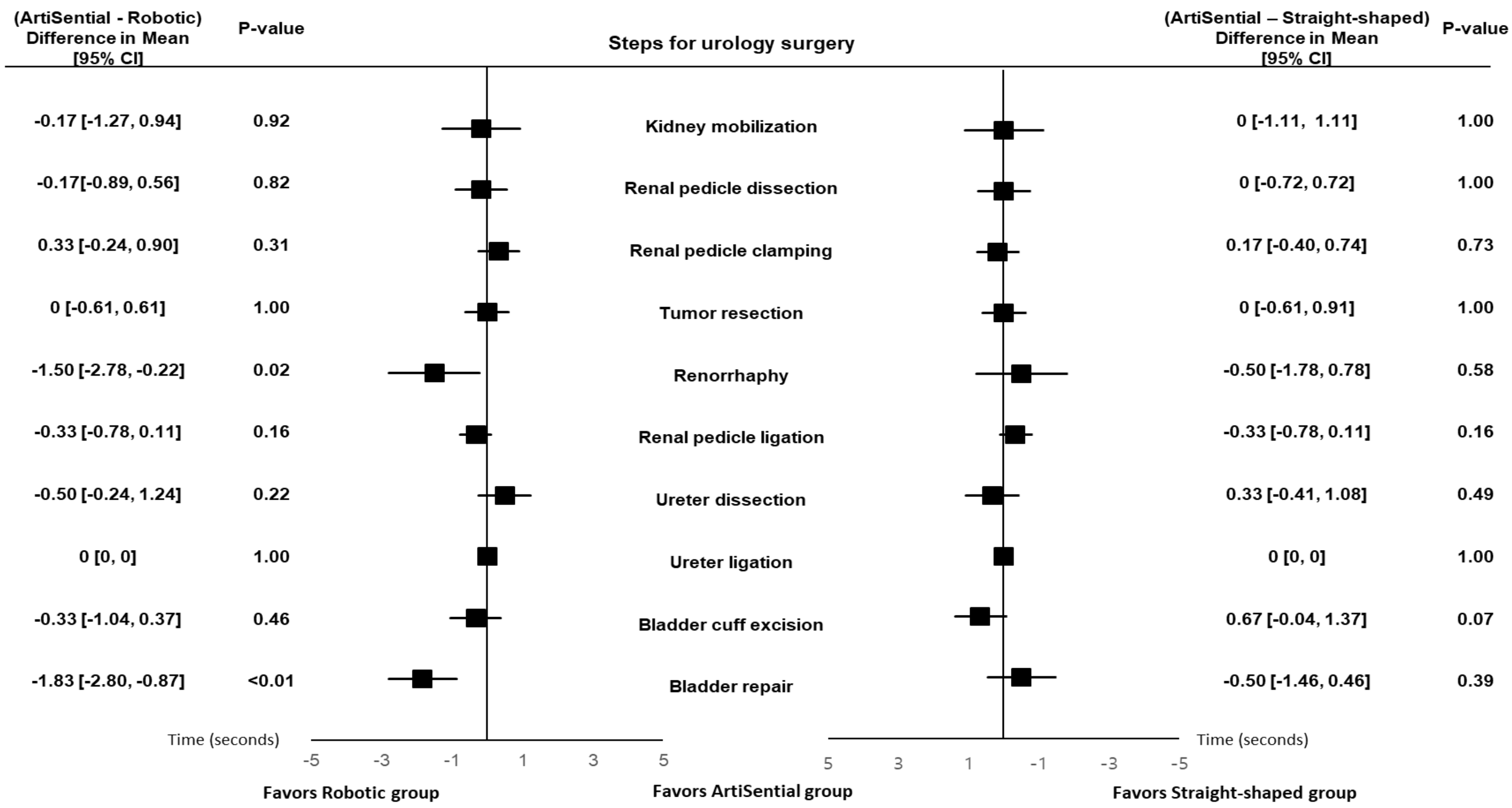

Figure 5. Illustration of a forest plot for difference in useability within each group

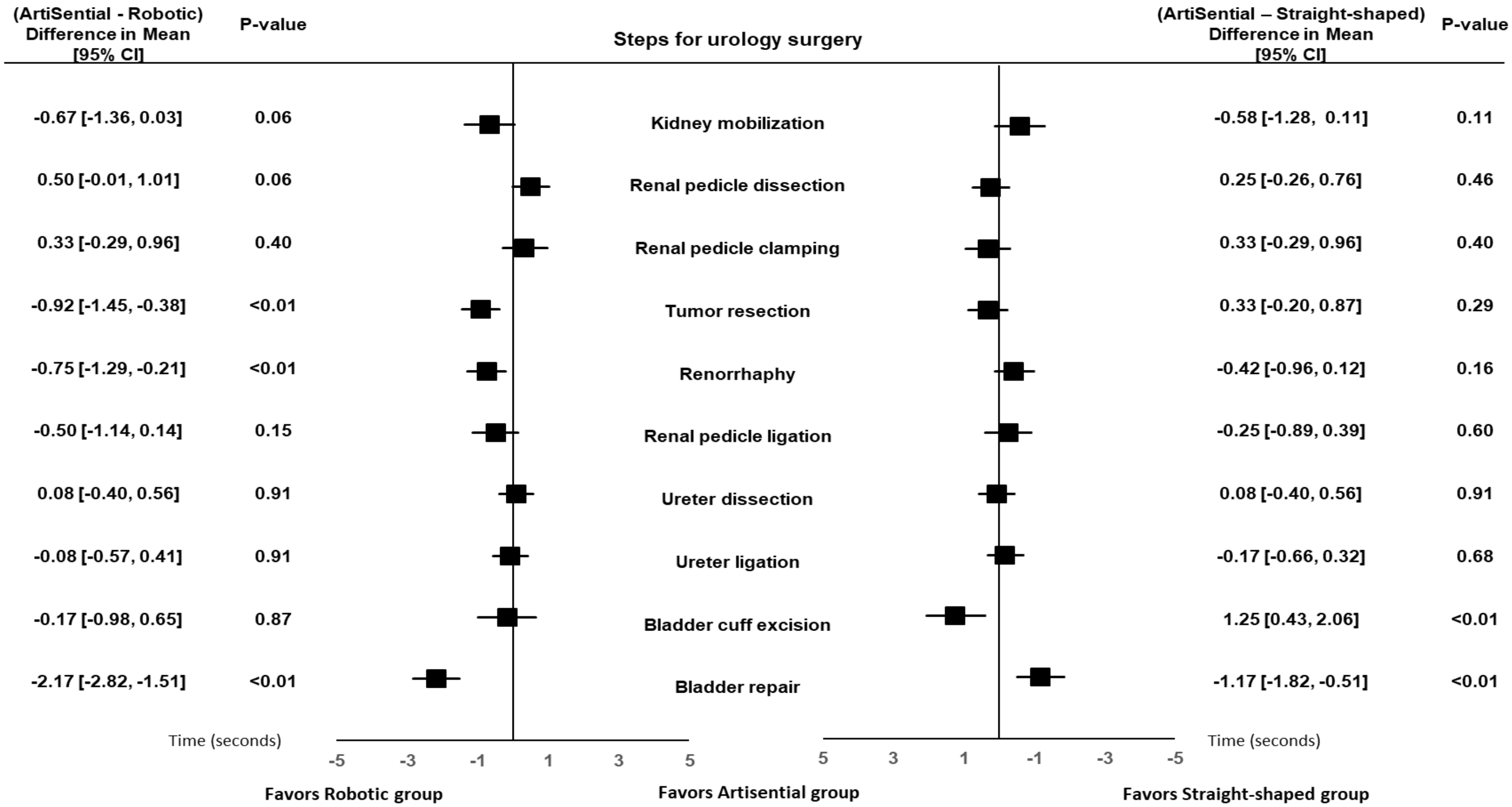

Figure 6. Illustration of a forest plot for difference in accuracy within each group

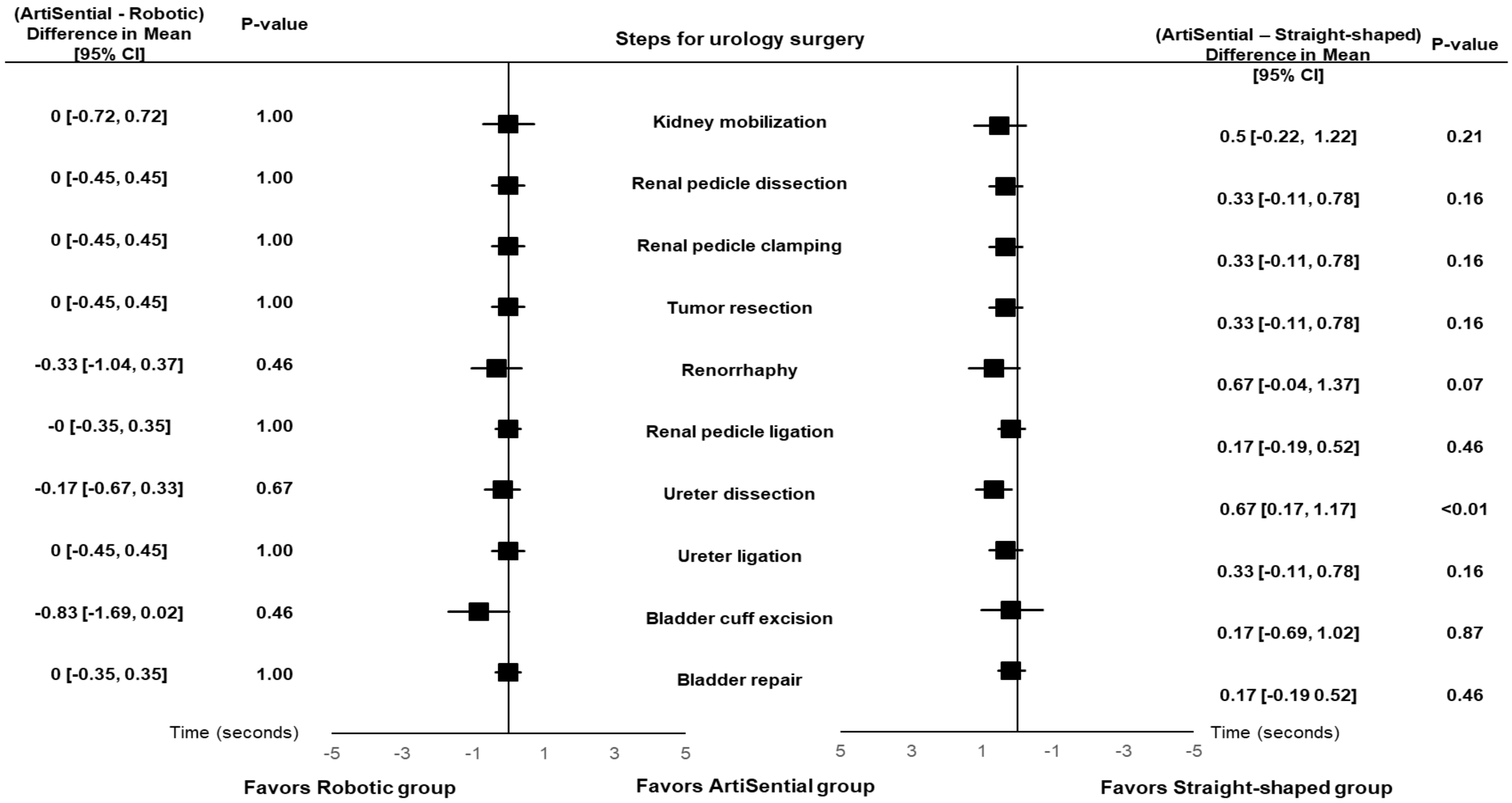

Figure 7. Illustration of a forest plot for difference in hands stress within each group

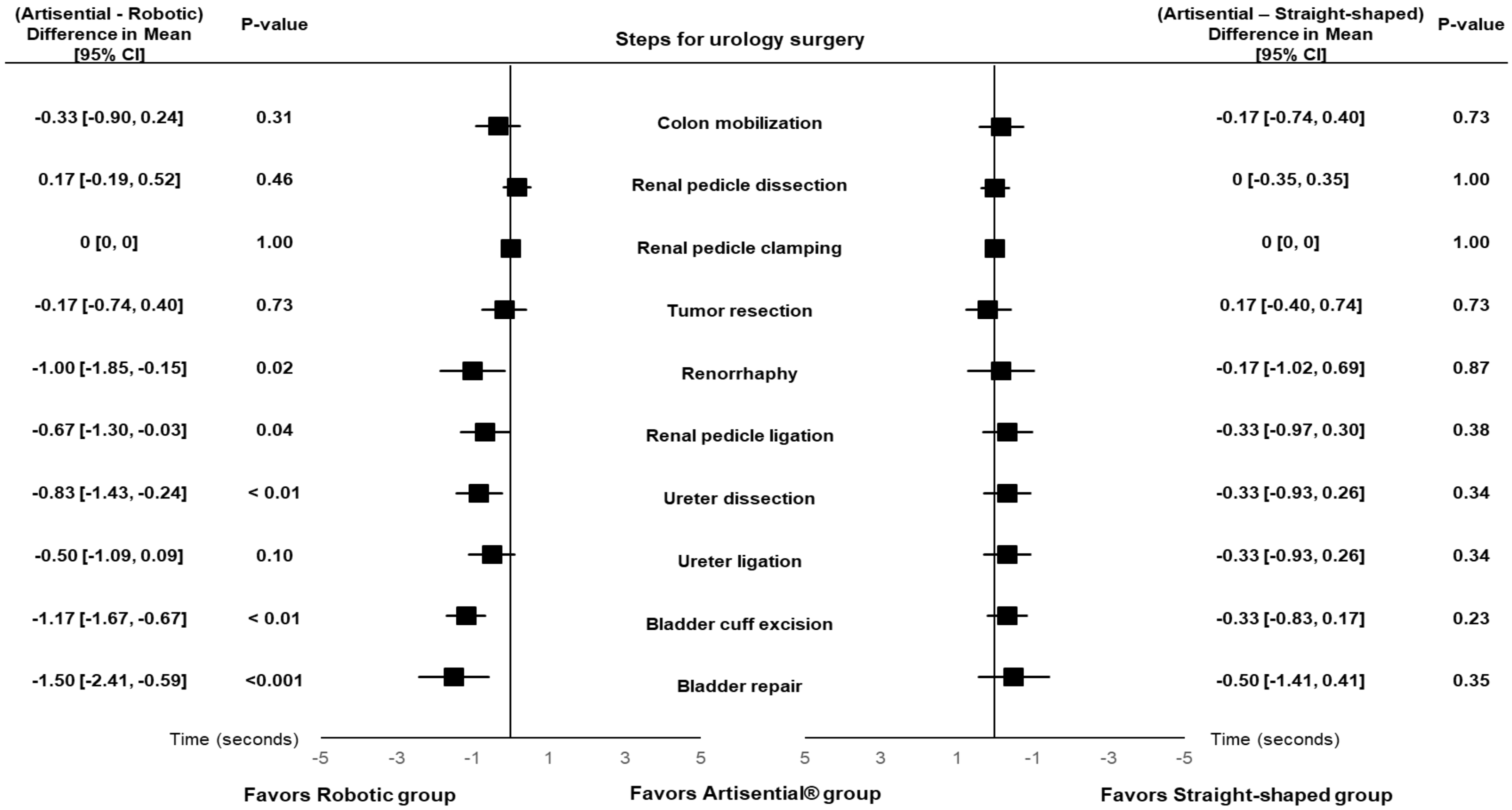

Figure 8. Illustration of a forest plot for difference in wrists stress within each group

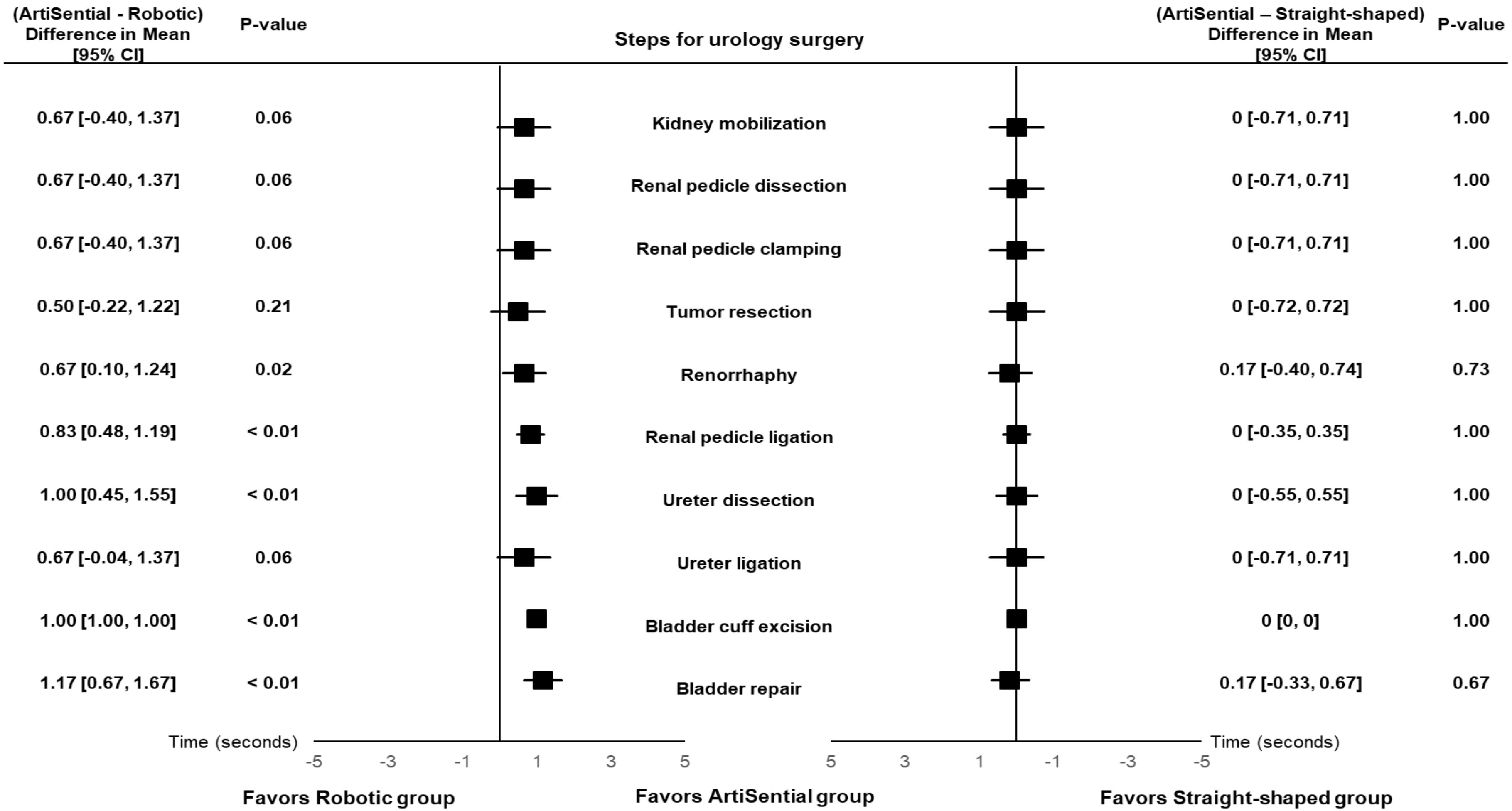

Figure 9. Illustration of a forest plot for difference in back stress within each group

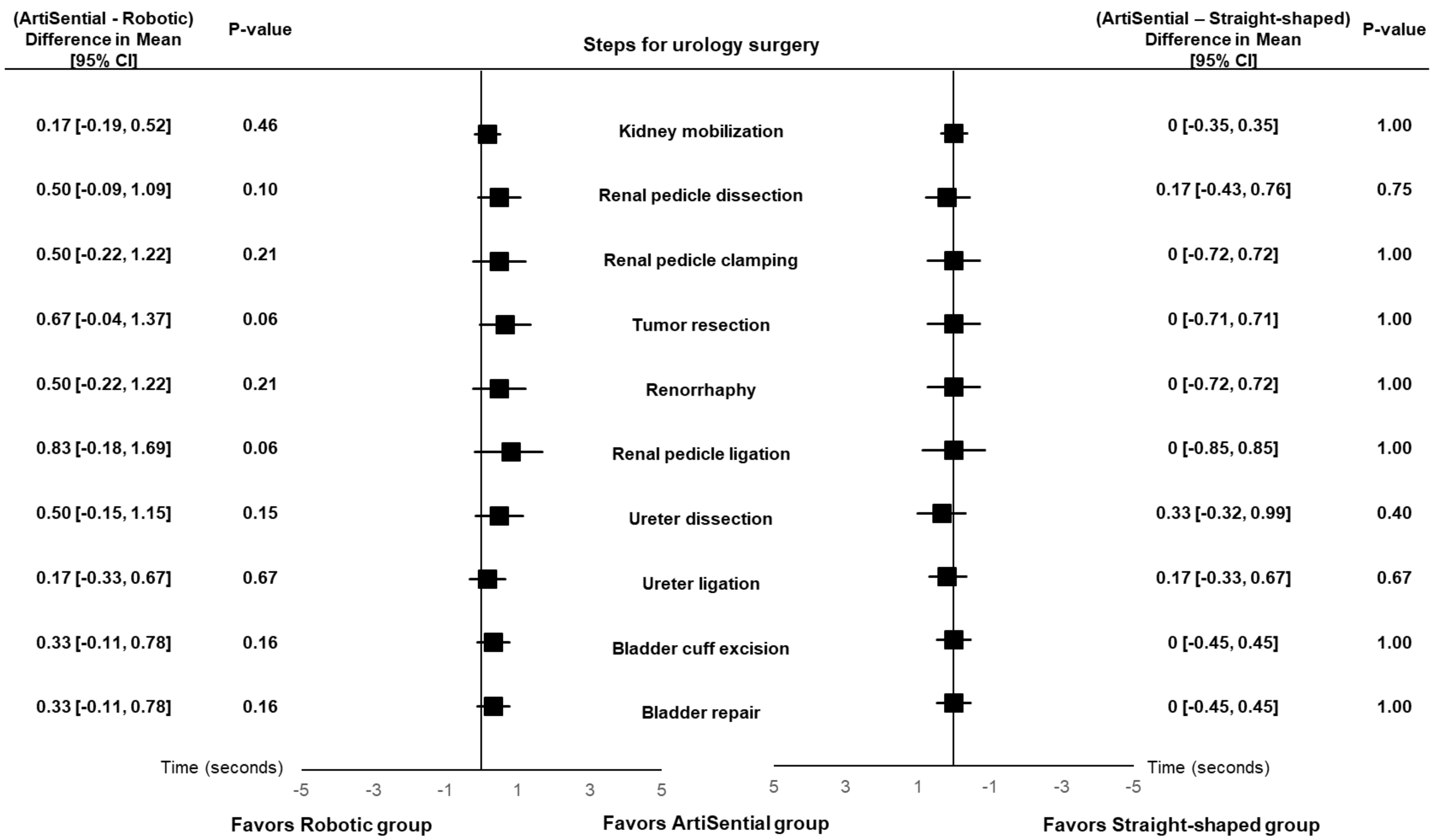

Figure 10. Illustration of a forest plot for difference in neck discomfort within each group

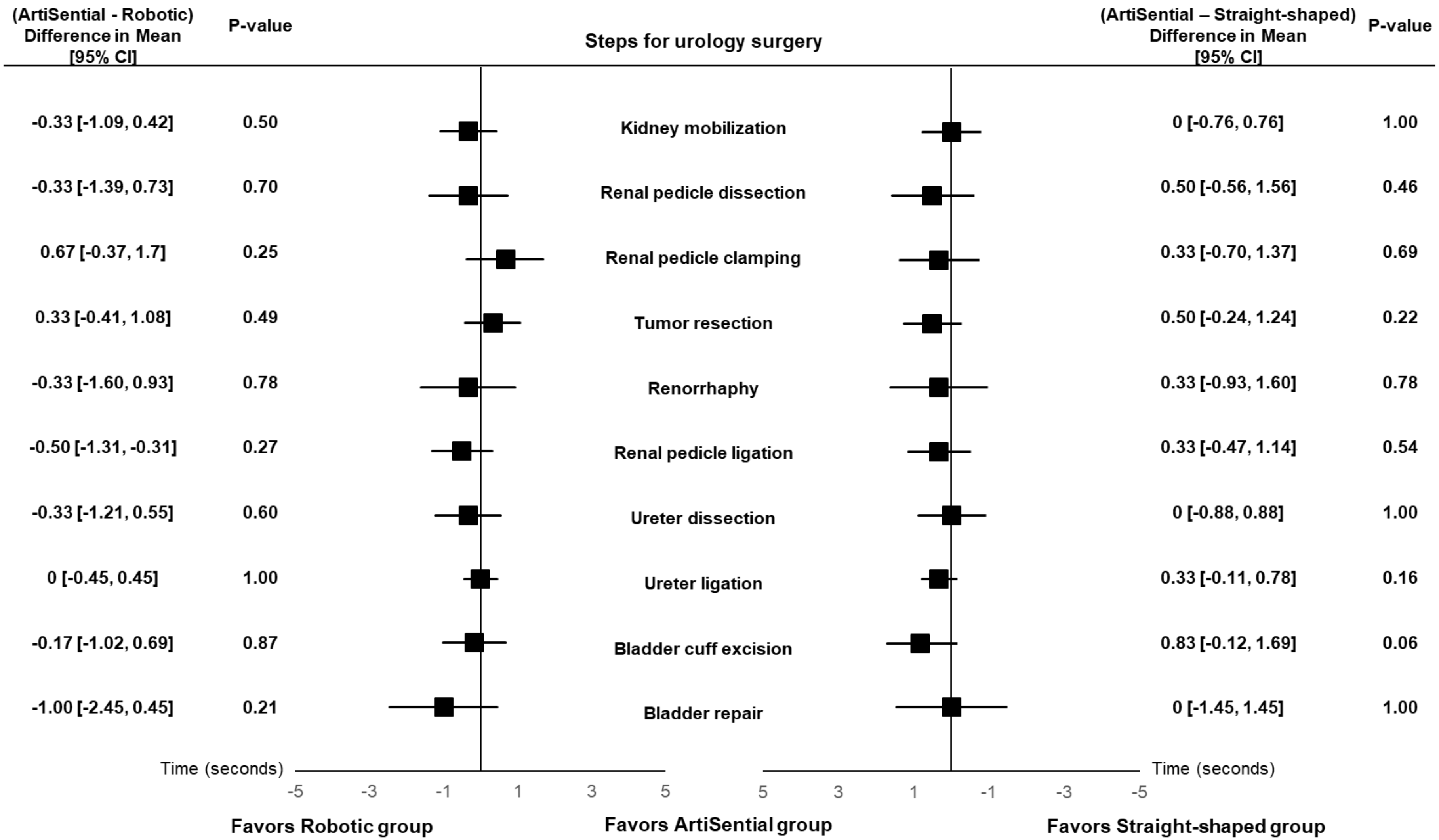

Figure 11. Illustration of a forest plot for difference in shoulders discomfort within each group

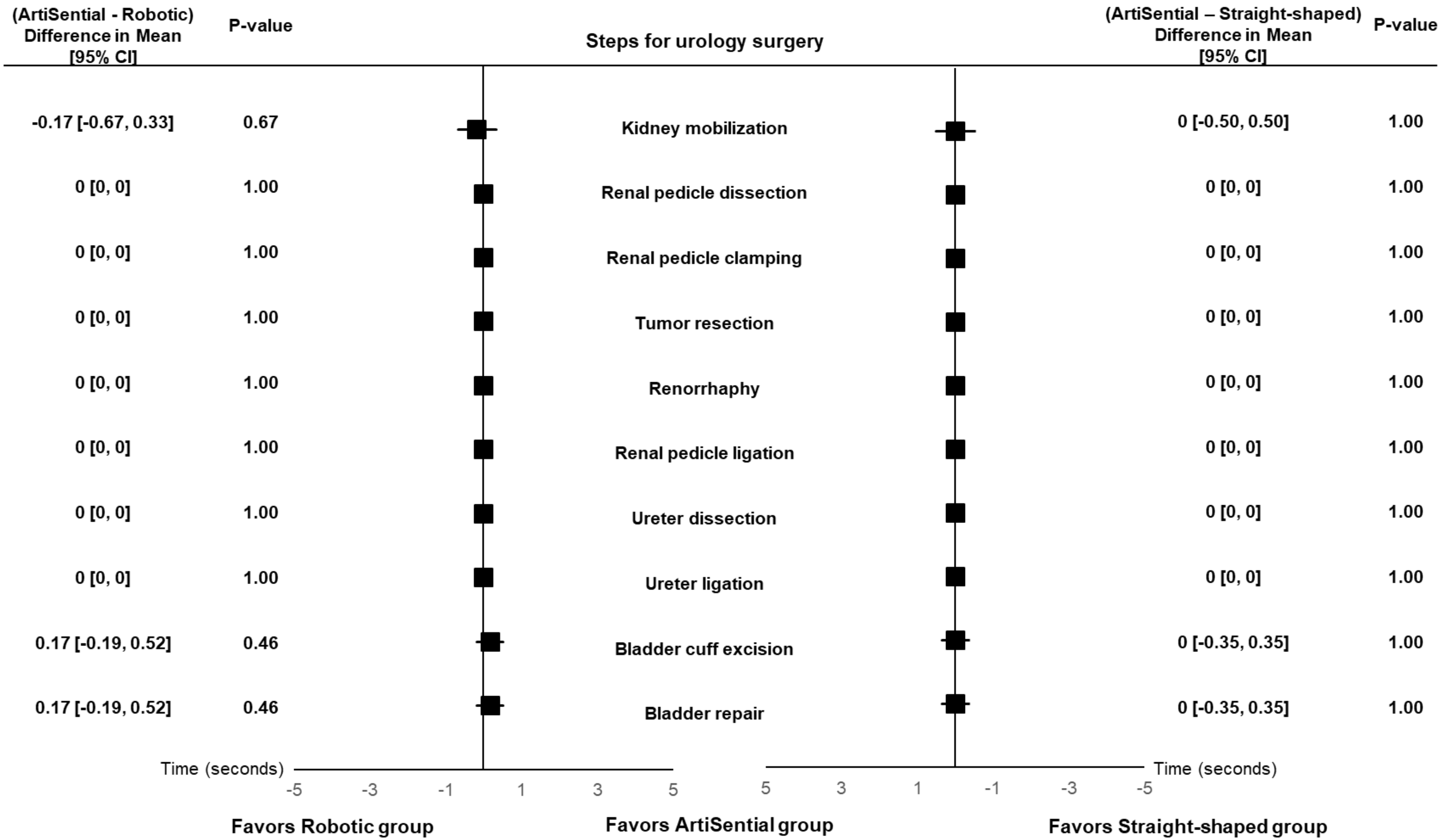

Figure 12. Illustration of a forest plot for difference in elbows discomfort within each group

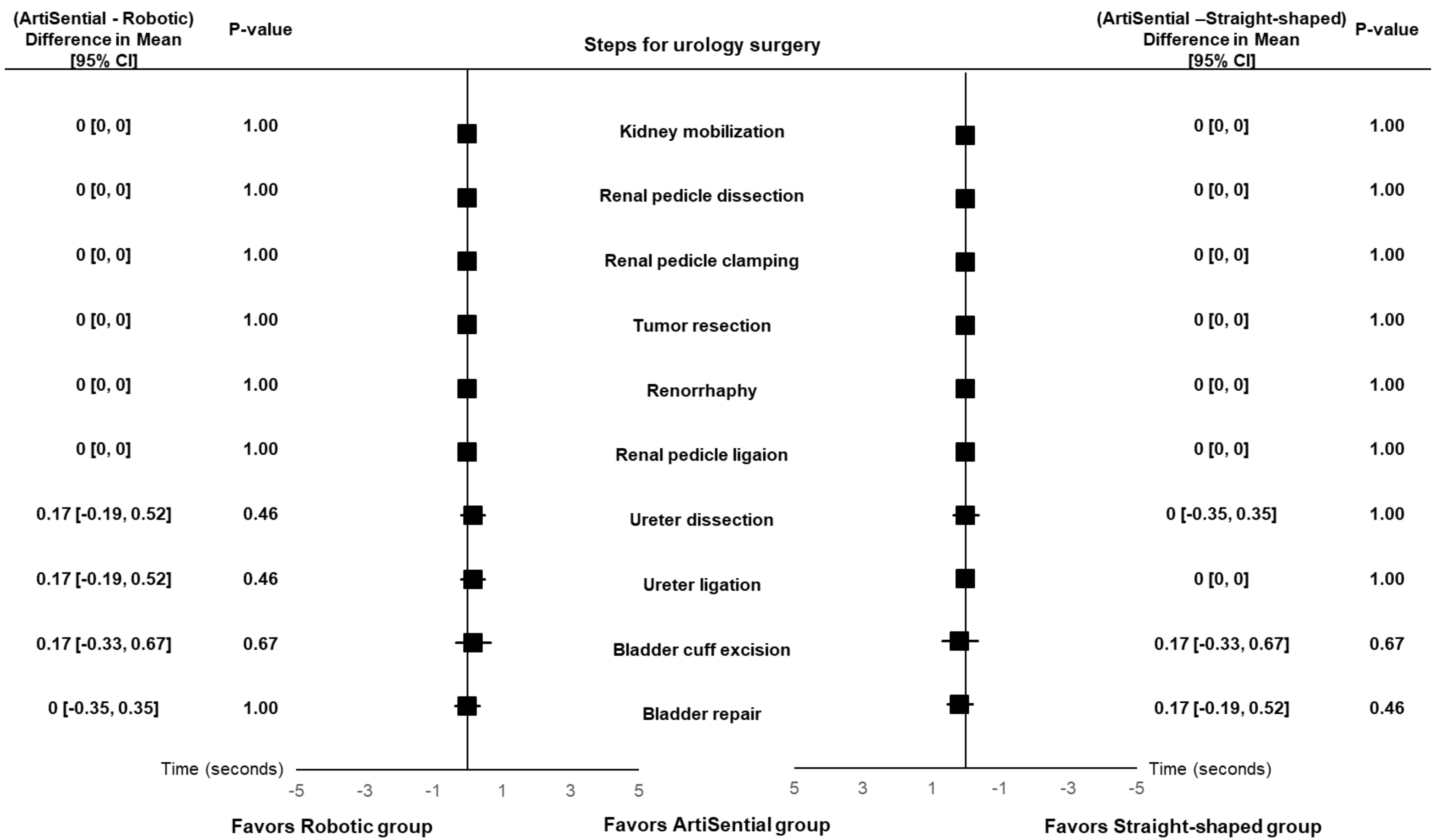

Figure 13. Illustration of a forest plot for difference in legs discomfort within each group

Discussion

Since the introduction of minimally invasive surgeries, there has been substantial advances in laparoscopic devices, notably the widespread implementation of laparoscopic surgery and the robotic system. According to several studies, laparoscopic surgery has been shown to be comparable to robotic surgery with respect to clinical feasibility.[3,4,10-13] This study has confirmed that the ArtiSential devices, developed to facilitate unrestricted joints mobility up to 360°, demonstrate comparable usability and accuracy to robotic arms or conventional laparoscopic instruments in almost surgical steps, with the exception of those that require suturing. Notably, in the context of ureter dissection, which requires a wider surgical field and frequent adjustments of the operator's view, the ArtiSential group was found to require significantly shorter operation time compared to the robotic group, while musculoskeletal discomfort was comparable between ArtiSential devices and traditional laparoscopic instruments. Moreover, ArtiSential surgery resulted in lower levels of back stress when compared to robotic surgery.

This study findings indicate that the ArtiSential device was observed to be comparatively less usable and less accurate in performing renorrhaphy and bladder repair when compared to the robotic system. In a conventional laparoscopic setting, the established technique for suturing entails maintaining a parallel placement of suture site and the needle holder, which provides both comfort and efficiency during the procedure. In some instances, it may be necessary to manipulate the tissue, such as by pulling or pushing, to achieve the required angles.[14] The enhanced convenience of suturing in robotic surgery can be attributed to the articulated capabilities of the robotic arm, which allows for nearly all of its instruments to manipulate tissue and devices with movements that closely mimic those of a human wrist [2,15] The robotic instrument can approach the surgical site at an optimal angle with minimal manipulation required.[15,16] Also, the robotic system was equipped with a fourth arm that maintained the optimal suture angle, allowing the operator to perform suturing with ease using simple movements.[11,17,18] The judicious use of the fourth arm facilitated the surgeon in achieving optimal surgical positioning during several procedures, including the handling of the kidney, hilar dissection, and renal vascular control, obviating the need for surgical assistants at the site.[19,20] In the ArtiSential group, the surgeon was required to exert greater force while using the needle holder due to the weight of the device's head. This weight may limit the range of motion permitted at the joint.[21,22] Furthermore, the ArtiSential needle holder lacked a mechanism for securing the needle in place, placing significant strain on the surgeon's fingers.

Blood loss and intraoperative complications did not significantly differ among the three groups. Previous studies have shown that the use of robotic systems in radical nephrectomy does not increase the risk of blood loss compared to laparoscopic surgery. Moreover, the robotic system was found to be comparable to laparoscopic surgery in terms of patient safety in renal surgeries such as radical nephrectomy, partial nephrectomy, and nephroureterectomy with bladder cuff excision with respect to intraoperative complications.[10,12,13] In this study, it was observed that a bowel injury occurred in the robotic group due to loss of touch perception of the robot arm during device insertion. Moreover, in one case of straight-shaped group, the main artery was cauterized by the surgeon because of insufficient exposure of the field of interest caused by inadequate angulation of the conventional laparoscopic instrument. The authors anticipate that the ArtiSential device may help overcome these limitations of the other instruments by providing intact touch perception to the surgeon and wrist-like performances of the instrument tip.[7,8]

A previous study indicated that laparoscopic surgery activates more muscle groups compared to robotic surgery, implying that robotic surgery has an ergonomic advantage over laparoscopic surgery.[23] In the present study, the level of musculoskeletal stress induced by the ArtiSential instrument was found to be comparable to that of the straight-shaped instrument. Interestingly, it was anticipated that the use of the ArtiSential instrument would result in similar wrist stress for the surgeon due to its enhanced wrist joint usability in comparison to the robotic system. However, contrary to expectations, the ArtiSential group was associated with greater wrist stress during bladder repair than the robotic group. This was particularly notable when extensive manipulations were required within a narrow surgical space, such as during renorrhaphy, renal pedicle ligation, bladder cuff excision, and bladder repair. As the ArtiSential device is relatively heavy, it is primarily supported by the surgeon's wrist, which could result in significant wrist stress during suturing and fine dissection.[21,22] Reducing the weight of the ArtiSential instrument and enhancing its capabilities to facilitate precise movements and suturing is imperative. Previous efforts to distribute wrist stress in the "limited articulated laparoscopic device" have shown promising results, with reported clinical safety and feasibility comparable to that of the robotic arms during surgeries involving suturing. [6,24,25]

In this preclinical study, a comparison was made among three groups using objective and subjective outcomes obtained from finely divided surgical steps. The parameters obtained from this study were then utilized to integrate and combine the detailed surgical stages based on Table 1, allowing for the prediction of a comparison among three representative surgeries: nephrectomy, partial nephrectomy, and nephroureterectomy with bladder cuff excision. In nephroureterectomy with bladder cuffing, which includes bladder repair requiring suturing in a narrow pelvic cavity, the robotic group demonstrated higher accuracy compared to the ArtiSential group. However, almost parameters showed non-inferior results between the two groups. (Table 4)

Table 4. Summary of each renal surgery in terms of objective and subjective parameters related to surgery.

Renal surgery	Parameters	Robotic group	ArtiSential group	Straight-shaped group	p-value
Radical nephrectomy	Operation time, min	35.7 ± 8.7	33.2 ± 8.2	27.8 ± 2.7	0.055
	Blood loss, ml	6.6 ± 3.9	9.0 ± 13.6	5.8 ± 3.5	0.717
	Useability (5 surgical steps)	23.7 ± 0.8	23.5 ± 1.8	23.5 ± 1.6	0.994
	Accuracy (5 surgical steps)	23.5 ± 1.0	22.7 ± 2.1	23.3 ± 1.1	0.881
	Intraoperation complication (total)	2	3	1	0.729
Partial nephrectomy	Operation time, min	36.0 ± 11.3	36.6 ± 9.8	30.0 ± 2.2	0.318
	Blood loss, ml	8.2 ± 5.4	11.9 ±14.3	7.4 ± 1.8	0.970
	Useability (5 surgical steps)	23.7 ± 1.0	22.2 ± 1.6	22.5 ± 1.0	0.193
	Accuracy (5 surgical steps)	23.3 ± 1.6	22.1 ± 1.6	22.3 ± 0.8	0.359
	Intraoperation complication (total)	1	3	0	0.304
Nephroureterectomy with bladder cuffing	Operation time, min	47.9 ± 9.1	58.8 ± 10.8	48.0 ± 2.9	0.054
	Blood loss, ml	9.6 ± 5.1	11.9 ± 15.7	9.3 ± 3.3	0.070
	Useability (6 surgical steps)	28.7 ± 0.8	26.3 ± 2.8	26.2 ± 1.7	0.053
	Accuracy (6 surgical steps)	27.8 ± 1.5	25.8 ± 0.7	25.4 ± 2.0	0.014*
	Intraoperation complication (total)	2	3	2	0.975

Our study has several limitations. First, because this experimental results may not be directly applicable to humans and cannot totally predict clinical outcomes.[26] Second, utilizing traditional surgical techniques with the newly introduced multi-articulating laparoscopic device may have adverse effects on surgical outcomes. Further investigation is required to assess whether there exists a significant learning curve for renal surgery employing articulating instrumentation. Also, to enable its clinical application in future studies, the ArtiSential instrument requires further enhancements to optimize its usability, and specialized surgical techniques must be developed to effectively utilize these novel instruments.

Conclusions

The ArtiSential instrument showed comparable performance to the da Vinci surgical system or straight-shaped instruments in almost steps, based on both objective and subjective parameters. Further improvements are needed for the ArtiSential instrument in terms of its suturing to enhance its usability. Additionally, developing specialized surgical techniques specifically for the ArtiSential instrument can maximize its advantages.

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국문요약

연구목적: 본 연구는 비뇨의학과 신장 수술 분야에서 새로운 다중 자유 관절 복강경 기구인 ArtiSential 기구를 고식적인 복강경 직선형 기구 또는 다빈치 로봇 수술 시스템과 비교하였다.

연구방법: 9마리의 암컷 Yorkshire 돼지를 ArtiSential 군, Straight-shaped 군, Robotic 군으로 총 3개 그룹으로 균등하게 분배하여 각 군당 6개의 신장을 수술하였다.

근치적 신절제술, 부분신절제술, 신장-요관-방광절제술에 대해 10개의 수기 단계로 세분하였으며, 각 수술 단계에서 수술 시간과 실혈량의 객관적 결과와 사용성, 정확도과 술자의 관절 피로도의 주관적 결과를 평가하고 그룹간 비교하였다.

연구결과: ArtiSential 군에서는 Robotic 군에 비해 혈관경 고정(renal pedicle clamping) 및 요관 박리의 평균 수술 시간이 유의하게 짧았다 (1.4 min vs. 5.5 min, $p<0.01$; 7.2 min vs. 11.3min, $p=0.01$). 그러나 ArtiSential 군에서 방광 봉합의 평균 수술 시간은 Robotic 군 및 Straight-shaped 군보다 유의하게 길었다 (16.0 min vs. 5.9 min 및 16.0 min vs. 9.4 min, 두 경우 모두 $p<0.01$). 수술 중 실혈량 또는 합병증에서는 그룹 간 유의한 차이가 없었다. ArtiSential 기구는 로봇 팔에 비해 신장 복원 (renorrhaphy) 및 방광 봉합에서 사용성이 낮았다 ($p=0.02$, $p<0.01$). 또한 ArtiSential 군은 종양 절제, 신장 복원, 및 방광 수복에서 Robotic 군에 비해 정확도가 낮았다. 술자는 ArtiSential 군에서 신장 동맥 결찰, 요관 박리, 요관구 주위 방광점막절제술, 신장 복원 및 방광 봉합 중 손목의 불편증은 크게 느껴졌지만 허리의 불편증은 Robotic 군에 비해 적었다.

결론: 대부분의 수술 단계에서, ArtiSential 기구는 로봇 및 직선형 기구와 비교 가

능한 성능을 보였다. ArtiSential의 잠재적 장점은 전문적인 수술 기술의 발전을 통해 더욱 최적화될 수 있다.

중심단어; 관절, 복강경, 로봇, 신장