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Comparison of conventional and castroviejo needle holders in terms of vascular anastomosis time in renal transplant

Böbrek naklinde vasküler anastomoz zamanı açısından konvansiyonel portegü ile castroviejo portegünun karşılaştırılması

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ÖZET

Amaç: Renal vasküler yapıların anastomoz süresinin uzamaması, sıcak ve soğuk iskeminin potansiyel zararlı etkisini en aza indirmek adına önemlidir. Çalışmamızın amacı, renal transplantasyon esnasında vasküler anastomozda kullanılan portegü tasarımının, anastomoz süresine olan etkisini belirlemektedir.

Gereç ve Yöntemler: Eylül 2011 ve Şubat 2020 tarihleri arasında kliniğimizde yapılan böbrek nakli vakaları retrospektif olarak incelendi. Anastomozlarda kullanılan iki tip portegüye göre hastalar gruplara ayrıldı. Grup 1'de konvansiyonel tipte, Hegar tipi makas tutucusuna sahip Ryder Diadust, düz, 180mm (7") portegü kullanılmıştır. Grup 2'de, kalem portegü tipinde, Castroviejo Durogrip TC Micro Needle Holder, düz, 215mm (8 ½") kullanılmıştır. Her iki grup arasında demografik özellikler, vasküler karakteristikler ve vasküler anastomoz süreleri karşılaştırılmıştır.

Bulgular: Toplam 75 hasta çalışmaya dahil edildi. Grup 1'de toplam 39 (52%), Grup 2'de 36 (48%) hasta mevcuttu. Tüm hasta grubunda ortalama arter sayısı 1,2 ± 0,4, ortalama arter çapı 5,3 ± 1,2 mm bulunmuş olup, her iki grup arasında bu değerler arası istatistiksel anlamlı fark yoktu (p=0,196 ve 0,304, sırasıyla). Ortalama arteryal anastomoz süresi Grup 1'de 15 ± 5,1, Grup 2'de 10 ± 3,9 dakikadır. Ortalama venöz anastomoz süreleri ise Grup 1'de 18,4 ± 6,1 ve Grup 2'de 14,7 ± 4 dakikadır. Yapılan istatistiksel analizde Grup 2'de arteryal ve ven anastomoz sürelerinin anlamlı olarak Grup 1'den daha kısa olduğu bulunmuştur (p= 0,038 ve p= 0,020, sırasıyla).

Sonuç: Çalışmamızda, renal transplant esnasında yapılan anastomozda kalem tipi Catroviejo portegü kullanılan grupta renal arterial ve venöz anastomoz sürelerinin anlamlı olarak daha kısa olduğu bulunmuştur.

Anahtar Kelimeler: *böbrek nakli, vasküler anastomoz, portegü*

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This study was approved by the Ethics Committee of University of Health Sciences, Dr.Sadi Konuk Training and Research Hospital Ethical Committee(Approval Number: 2022-12-17, Date: 20/06/2022). All research was performed in accordance with relevant guidelines/regulations, and informed consent was obtained from all participants.

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ABSTRACT

Objective: It is important that the anastomosis time of renal vascular structures is not prolonged to minimize the potentially harmful effect of warm and cold ischemic times. This study aimed to determine the effect of the needle holder design used in vascular anastomosis during renal transplantation on the duration of anastomosis.

Material and Methods: Patients that underwent renal transplantation at our clinic between September 2011 and February 2020, were divided into groups according to the two types of needle holders used in anastomoses. In Group 1, a conventional, Hegar-type, straight, 180-mm (7") Ryder Diadust needle holder was used. In Group 2, a pen-type, straight, 215-mm (8 ½") Castroviejo Durogrip TC micro needle holder was used. Demographic characteristics, vascular characteristics, and vascular anastomosis times were compared between the two groups.

Results: A total of 75 patients were included in the study. There were 39 (52%) patients in Group 1 and 36 (48%) patients in Group 2. The mean number of arteries was 1.2 ± 0.4, and the mean arterial diameter was 5.3 ± 1.2 mm in the whole cohort, with no statistically significant difference between the two groups (p=0.196 and 0.304, respectively). The mean arterial anastomosis time was 15 ± 5.1 minutes in Group 1 and 10 ± 3.9 minutes in Group 2. The mean venous anastomosis times were 18.4 ± 6.1 in Group 1 and 14.7 ± 4 minutes in Group 2. In the statistical analysis, the arterial and vein anastomosis times were found to be significantly shorter in Group 2 than in Group 1 (p=0.038 and p=0.020, respectively).

Conclusion: In our study, it was observed that the renal arterial and venous anastomosis times were significantly shorter in the group in which the pen-type Castroviejo needle holder was used in anastomoses performed during renal transplantation.

Keywords: *renal transplant, vascular anastomosis, needle holder*

INTRODUCTION

During renal transplantation, the warm ischemia period in which the kidney is removed from ice but reperfusion is not yet achieved is called anastomosis time. Previous studies have shown that a prolonged anastomosis time has a negative effect on delayed graft function (DGF) (1-3).

Ensuring the successful anastomosis of blood vessels is critical in many modern surgical procedures. It is usual to perform vessel anastomosis not only for organ transplants but also for other procedures, such as post-traumatic vessel repairs and free tissue transfers under a microscope (4). It is important that the anastomosis time of renal vascular structures is not prolonged to minimize the potentially harmful effect of warm and cold ischemic times. The success of anastomosis depends on the meticulous application of the technique with appropriate tools (1). The needle holder should be suitable for the suture size and depth (5). Choosing the right surgical instrument has the potential to be an influencing factor in surgical success.

With the evolution of modern surgical techniques, the importance of the design of surgical instruments has increased (6). The physical differences of surgeons require the design of instruments in a wide range of power and size, which is further necessitated by the increased risk of musculoskeletal diseases due to occupational reasons (7). The choice of size for the needle holder depends on the purpose and size of the suture, and the surgeon's preference. Although there are only limited studies on the effect of the needle holder design on the surgical technique, the Frimand needle holder has been shown to reduce suturing time and surgical stress in the experimental setting (8).

This study aimed to determine the effect of the needle holder design used in vascular anastomosis during renal transplantation on the duration of anastomosis.

MATERIAL AND METHODS

Patients that underwent renal transplantation at our clinic between September 2011 and February 2020 were retrospectively evaluated and included in the study. The study included cases in which venous anastomosis to the external iliac vein and arterial anastomosis to the external iliac artery had been performed. Patients that did not undergo primary renal transplantation and those with autosomal dominant

polycystic kidney disease, concomitant native nephrectomy, or vascular pathologies that would seriously affect the anastomosis were excluded from the study. In addition, patients who underwent end-to-end vascular anastomosis were excluded from the study. In addition to the demographic characteristics of the patients, the number of graft vessels, and the duration of arterial and venous anastomoses were recorded. The mean diameter of an artery was calculated by summing the diameters of all arteries and dividing the result by the total number of arteries. The mean anastomosis time of an artery was calculated by summing the anastomosis times of all arteries and dividing the result by the total number of arteries. The mean arterial anastomosis time per mm arterial diameter was determined by dividing the mean anastomosis time by the mean arterial diameter. The venous anastomosis time and the mean venous anastomosis time per mm vessel diameter were calculated in a similar manner. The arterial anastomosis time was defined as the time taken to perform the anastomosis of the renal artery to the external iliac artery, and the venous anastomosis time as the time taken to perform the anastomosis of the renal vein to the external iliac vein.

Two types of needle holders were used in anastomoses, and the patients were divided into two groups accordingly. In Group 1, a conventional, Hegar-type, straight, 180-mm (7") Ryder Diadust needle holder was used. In Group 2, a pen-type, straight, 215-mm (8 ½") Castroviejo Durogrip TC micro needle holder was used. Demographic characteristics, vascular characteristics, and vascular anastomosis times were compared between the two groups.

Surgical Technique:

Our transplant team consisted of four people, two working on donor nephrectomy and two on the recipient transplant procedure. Living donor nephrectomies were performed laparoscopically via the transperitoneal route. All the kidneys evaluated in the study, including those of cadaveric origins were left kidneys. All the graft kidneys were placed retroperitoneally in the right iliac fossa. The kidney transplant procedure was performed by two surgeons (A.F.G., S.K.) and both were experienced in the use of both needle holders. The preference for the use of needle holders was determined according to the personal preferences of the surgeons on a case-by-case basis.

Incision Site and Length

Epilation was performed with a shaver on the morning of the surgery. After the patient was placed on the operating table, povidone iodine was used with a sponge for the first wash, and regular povidone iodine was used twice for the final preparation. The incision started from the point where the angle formed by the transverse line drawn from the navel and the umbilical-spina iliaca anterior superior line intersected the lateral side of the rectus muscle, as previously described in the literature (9).

The epigastric arteries in all patients and the round ligament in women were usually dissected to allow exposure, but the spermatic cord was protected by retracting it medially by releasing the border of the inguinal canal. Penetration into the peritoneal cavity was avoided, and any opening in the peritoneum was repaired before continuing with the incision. Strict bleeding control was applied before the kidney was placed. After entering the retroperitoneal space and revealing the anatomy of the iliac vessels and confirming their suitability for transplantation, the vessels were prepared by ligating all lymphatics.

Anastomosis

After preparing the implantation site, the graft was placed in its temporary position for the better evaluation of the anastomotic site. The external iliac artery and external iliac vein were used as the first choice in vascular anastomoses. To prevent twisting or rotation, vessel clamps were used after confirming the exact length and position of the anastomotic site. The Bulldog clamp was preferred for the internal iliac artery and vein, and the Satinsky clamp for the side clamping of the external iliac and common iliac arteries. Heparinized isotonic solution was used for vascular irrigation. For end-to-side anastomosis, the lower corner of the graft artery was spatulated. Arterial anastomosis was started by placing sutures at two corners, as described by Carrel and Gutrie in 1905 (10). Posterior arterial anastomosis was performed firstly. Since the needle is considered to be weaker than the host artery, the needle was passed from inside to

outside in the renal artery and from outside to inside in the host artery to prevent intimal separation. Then, the posterior layer was sutured, and anterior layer anastomosis was started from both corners. The entire anastomosis procedure was performed circumferentially with a single proximal corner suture. 6-0 Prolene sutures were used for venous and arterial anastomoses. Ureteral anastomosis was performed with the extravesical modified Lich-Gregoir technique.

Categorical data were presented as numbers and percentages. Data on continuous variables were presented as mean and standard deviation. Normally distributed data were compared between the two groups using the dependent-samples t-test, and non-normally distributed data using the Mann-Whitney U test. Frequencies of categorical variables were compared using the Pearson chi-square test. A p value of <0.05 was considered statistically significant. Statistical analyses were performed using the Statistical Package for the Social Sciences version 21 (IBM SPSS Statistics; IBM Corp., Armonk, USA).

RESULTS

After applying the inclusion and exclusion criteria, a total of 75 patients were included in the study. The patients' demographic data, arterial characteristics, and anastomosis times are given in Table 1. The mean age of the patients was 38.7 ± 13.3 years. Fifty (66.7%) patients were male and 25 (33.3%) were female. There were 39 (52%) patients in Group 1 and 36 (48%) in Group 2. There was no significant difference between the two groups in terms of age and gender (p = 0.103 and p = 0.148, respectively). The mean number of arteries was 1.2 ± 0.4, and the mean arterial diameter was 5.3 ± 1.2 mm in the whole cohort, with no significant difference between the two groups (p = 0.196 and 0.304, respectively). The mean arterial anastomosis time was 15 ± 5.1 minutes in Group 1 and 10 ± 3.9 minutes in Group 2. The mean venous anastomosis times were 18.4 ± 6.1 minutes in Group 1 and 14.7 ± 4 minutes in Group 2. In the statistical analysis, the arterial and venous anastomosis times were found to be significantly shorter in Group 2 than in Group 1 (p = 0.038 and p = 0.020, respectively).

Table 1. The patients' demographic data, arterial characteristics, and anastomosis times

Parameters (mean ± SD)	Total n = 75	Conventional needle holder n = 39 (52%)	Castroviejo needle holder n = 36 (48%)	p
Age (years)	38.7 ± 13.3	41.7 ± 13.8	35.5 ± 12.2	0.103*
Gender (n ; %)				0.148"
Male	50 (66.7)	28 (71.8)	22 (61.1)	
Female	25 (33.3)	11 (28.2)	14 (38.9)	
Number of arteries	1.2 ± 0.4	1.1 ± 0.3	1.2 ± 0.5	0.196*
Arterial diameter (mm)	5.3 ± 1.2	5.1 ± 0.8	5.5 ± 1.6	0.304*
Arterial anastomosis + (min)	11 ± 4.2	15 ± 5.1	10 ± 3.9	**0.038&**
Venous anastomosis + (min)	16.6 ± 5.5	18.4 ± 6.1	14.7 ± 4	**0.020***

**Independent-samples t-test "Chi square & Mann-Whitney U test + presented as median (interquartile range)*

DISCUSSION

In renal transplant, the duration of cold ischemia is one of the most important risk factors for DGF, inferior graft survival and function (11). However, until recently, only little was known concerning the effects of warm ischemia time on both short-term and long-term renal allograft function (12). It is suggested that warm ischemia time plays a key role in DGF after renal transplantation with both cadaveric and living donor procedures (2,3). Warm ischemia time refers to two different periods in the transplantation process: the first is related to organ harvesting and the second is related to the time of vascular anastomosis in the recipient. The temperature of the graft can rise rapidly to the metabolic threshold of 15 °C within 20 minutes of removing the kidney from ice. The heating of the graft increases cellular metabolism and leads to potentially

harmful changes in the transplanted kidney (13). DGF is important since it may lead to longer hospital stay and need for dialysis, resulting in impaired renal allograft function and shorter survival (12). In the literature, the most important evidence is related to the detrimental effect of warm ischemia time on renal function in partial nephrectomy (14). In a study examining the partial nephrectomy of solitary kidneys, it was found that each minute of warm ischemia was associated with a 6% increase in the risk of acute kidney injury and a 4% increase in the risk of new-onset end-stage renal disease (15). In the current study, we examined the arterial and venous anastomosis times separately rather than directly evaluating the warm ischemia time or anastomosis time. We determined that both arterial and venous anastomosis times were significantly shorter in the group where the pen-type Castroviejo needle holder was used compared to the conventional needle holder group.

Conventional needle holders are based on scissor configuration, and although this is sufficient in standard operations, it may be insufficient in cases requiring deep and narrowly located vascular and plastic suturing. A conventional needle holder can only be comfortably rotated up to 180° in the hand, and squeezing and unwinding the needle cause the momentary loss of control. This creates a serious handicap in cases like vascular anastomosis (16).

The Webster needle holder, which has a similar design to the Ryder Diadust needle holder we utilized in our study, uses the wrist that supinates between the supinator and external muscles and the radius and ulna, much like holding a fork. On the contrary, a pen needle holder (e.g., Castroviejo needle holder) requires finger twisting between the thumb and index finger and the inner and outer muscles of the middle finger, just like holding a pen or sticks, and it consists an important role mainly in microsurgery (17). It is designed for smooth and fine stitching, as there is less forearm muscle movement due to easy finger bending. The Castroviejo needle holder was patented in 1953 by Ramón Castroviejo, an ophthalmologist to be used for the above-mentioned purposes. The needle holder was originally designed to meet the need for fine instruments in ophthalmological procedures (18). The Hegar type consists of a forceps handle similar to the ends of a conventional needle holder, but the movement of the handle is reversed by the "X" configuration (16). In the locked position, it relieves tension on the fingers during needle manipulation. In the unlocked position, the needle holder is still able to hold objects under certain pressures. In addition, the Castroviejo needle holder can be easily rotated through wrist and finger manipulations (18). Compression tension is sufficient to hold the needle during normal suturing and will only loosen when subjected to unusual pressure that can bend or break the needle (16). The narrow handle occupies less space and allows for the stitched area to be seen more easily, and another advantage of this instrument is that it can be easily used with either hand.

To the best of our knowledge, there are very few studies in the literature comparing needle holder types in terms of anastomosis time and ergonomics. Ohata et al. compared pen-type and Hegar-type needle holders electromyographically in terms of forearm mobility during skin suturing (17). In that study, the microsurgeons were reported to perform less forearm movements with the pen needle holder, but the authors noted that this group was more experienced with this type of needle holder. Less experienced microsurgeons were accustomed to the webster type needle holders and had to do more forearm movement with the pen needle holder. They attributed this to 'motor skill learning'; i.e., the ability to use the tool almost automatically, without engaging attention or working memory, since they practiced it for a long time (19,20). This shows the importance of instrumentation habits of the surgeon as well as the design of the instrument. However, the surgeons in our study were proficient in both types of needle holders, which partially eliminates the experience variable in the comparison of anastomosis times.

Averay et al. investigated whether the type of needle holder had an effect on anastomotic construction time in an equine cadaver model. In end-to-end jejunojejunal anastomosis, they compared three needle holders (16.5 cm Frimand, 16 cm Mayo-Hegar, and 20.5 cm Mayo-Hegar) and stated that there was no significant difference in anastomosis times (21). The Frimand needle holder showed greater consistency in construction and suture times. In another article, it was reported that the design of the grip part of the

needle holder improved suturing performance, increased comfort, and reduced difficulties by providing a more appropriate wrist posture (5). There are also authors suggesting that more simulation and skill laboratory practice may be beneficial for surgeons to gain sufficient expertise prior to clinical practice in order to reduce anastomosis time and increase efficacy (11).

Our study has certain limitations, with two most important are its retrospective nature and limited number of patients. However, since the operations evaluated in our study were performed by two surgeons at a single center, the homogeneity of the cases made the comparison more significant despite the poor generalizability of the findings. In addition, since the choice of a needle holder will affect the anastomosis time depending on the operator's preference and experience, our results do not necessarily reveal the superiority of one instrument over the other. Lastly, the design of our study does not reflect the early and late effects of the difference in instrumentation on graft outcomes.

CONCLUSION

In our study, it was observed that the renal arterial and venous anastomosis times were significantly shorter in the group using a pencil type Castroviejo needle holder for anastomosis during kidney transplantation, compared to the group using a conventional needle holder. Shorter anastomosis times have the potential to reduce the duration of warm ischemia, and thus positively affect graft function. Further studies are needed in this regard.

Conflict of Interest: The authors declare to have no conflicts of interest.

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Ethical Approval: The study was approved by the Ethics Committee of University of Health Sciences, Dr.Sadi Konuk Training and Research Hospital (Decision No: 2022-12-17, Date: 20.06.2022). The study protocol conformed to the ethical guidelines of the Helsinki Declaration.

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REFERENCES

1. Heylen L, Naesens M, Jochmans I, et al. The effect of anastomosis time on outcome in recipients of kidneys donated after brain death: a cohort study. Am J Transplant. 2015; 15(11):2900-7 DOI: 10.1111/ajt.13397.
2. Rod X, Peyronnet B, Seisen T, et al. Impact of ischaemia time on renal function after partial nephrectomy: a systematic review. BJU Int. 2016; 118(5):692-705 DOI: 10.1111/bju.13580.
3. Hellegering J, Visser J, Kloke HJ, et al. Deleterious influence of prolonged warm ischemia in living donor kidney transplantation. Transplant Proc. 2012; 44(5):1222-1226 DOI: 10.1016/j.transproceed.2012.01.118.
4. Moritz WR, Raman S, Pessin S, et al. The History and Innovations of Blood Vessel Anastomosis. Bioengineering (Basel). 2022; 15;9(2):75 DOI: 10.3390/bioengineering9020075.
5. Abdelall ES, Stone RT, Rajana Nedved L, Fales C. Bend the Tool, Not the Wrist: An Ergonomic Investigation of Medical Suturing Needle Holder Design and Medical Engineering Solution. Surg Innov. 2021; 28(1):62-70 DOI: 10.1177/1553350620950896.
6. Van Veelen M, Meijer D, Uijttewaal I, Goossens R, Snijders C, Kazemier G. Improvement of the laparoscopic needle holder based on new ergonomic guidelines. Surg Endosc. 2003; 17(5):699–703 DOI: 10.1007/s00464- 002-9186-y.
7. Catanzarite T, Tan-Kim J, Whitcomb EL, Menefee S. Ergonomics in surgery: a review. Female Pelvic Med Reconstr Surg. 2018; 24(1):1–12 DOI: 10.1097/SPV.0000000000000456.

8. Frimand Rönnow C-F, Jeppsson B, Thorlacius H, et al. Frimand needle holder reduces suturing time and surgical stress when suturing in palm grip. Surg Innov. 2016; 23(3):235–41 DOI: 10.1177/1553350615610649.
9. Hacıislamogul A, Arıkan Y, Evren İ, et al. New Incision Method for Kidney Transplantation:Single-Center Experience. J Reconstr Urol. 2020; 10(3):75-9 DOI: 10.5336/urology.2020-76617
10. Carrel A, Guthrie CC. Functions of a transplanted kidney. Science. 1905;22:473.
11. Marzouk K, Lawen J, Alwayn I, Kiberd BA. The impact of vascular anastomosis time on early kidney transplant outcomes. Transplant Res. 2013; 2(1):8 DOI: 10.1186/2047-1440-2-8.
12. Ferede AA, Walsh AL, Davis NF, et al. Warm Ischemia Time at Vascular Anastomosis is an Independent Predictor for Delayed Graft Function in Kidney Transplant Recipients. Exp Clin Transplant. 2020; 18(1):13-18 DOI: 10.6002/ect.2018.0377.
13. Kuipers TG, Hellegering J, El Moumni M, et al. Kidney temperature course during living organ procurement and transplantation. Transpl Int. 2017; 30(2):162-169 DOI: 10.1111/tri.12892.
14. Becker F, Van Poppel H, Hakenberg OW, et al. Assessing the impact of ischaemia time during partial nephrectomy. Eur Urol. 2009; 56:625–634 DOI: 10.1016/j.eururo.2009.07.016.
15. Thompson RH, Lane BR, Lohse CM, et al. Every minute counts when the renal hilum is clamped during partial nephrectomy. Eur Urol. 2010; 58:340–345 DOI: 10.1016/j.eururo.2010.05.047.
16. Hawkins DB. A needle holder for vascular and plastic surgery. Am J Surg. 1976; 132(5):678. DOI: 10.1016/0002-9610(76)90376-7.
17. Ohata E, Matsuo K, Ban R, Shiba M, Yasunaga Y. Electromyographic comparison of forearm muscle movements for fine skin suturing between an enlarged pen needle holder and a webster needle holder. Eplasty. 2013; 6;13:e22. PMC3647241.
18. Yue Gao, Sharmila Dissanaike. The Castroviejo Needle Holder [Internet]. General Surgery News 2016 Available from: https://www.generalsurgerynews.com/Technology/Article/07-16/The-Castroviejo-Needle-Holder/38549.
19. Fitts PM. Perceptual-motor skill learning. In Melton AW, ed. Categories of Human Learning. New York, NY: Academic Press; 1964: 47-78.
20. Ohbayashi M, Ohki K, Miyashita Y. Conversion of working memory to motor sequence in the monkey premotor cortex. Science. 2003; 301:233-6. DOI: 10.1126/science.1084884
21. Averay K, van Galen G, Ward M, Verwilghen D. Effect of three different needle holders on gastrointestinal anastomosis construction time and bursting pressure in equine jejunal segments. BMC Vet Res. 2021; 17(1):167. DOI: 10.1186/s12917-021-02871-4.