

Horseshoe Kidneys: An Underutilized Resource in Kidney Transplant

Thomas Pontinen,¹ Kamran Khanmoradi,¹ Anil Kumar,³ Hussam Kudsi,¹ Shiang Cheng Kung,²
Daranee Chewaproug,² Radi Zaki,¹ Jorge Ortiz¹

Abstract

Objectives: Although the number of patients awaiting renal transplant is rapidly increasing, the donor pool has remained relatively stable. Horseshoe kidneys, a common renal fusion anomaly, can provide a useful solution to the ever-increasing gap between supply and demand.

Materials and Methods: These kidneys can be transplanted, en bloc, into a single recipient or divided and transplanted into 2 recipients.

Results: We report 2 cases of successful kidney transplants.

Conclusions: The first is a split horseshoe kidney, transplanted into a single recipient, and the second, a horseshoe kidney from a donor after cardiac death split and transplanted into a single recipient. The second case is the first reported case of a horseshoe kidney transplant from a donor after cardiac death. We also performed a review of the literature of horseshoe kidneys with the hope of raising awareness of the necessity and promise of such transplants.

Key words: Surgery, Donor, Congenital, Anomaly

The demand for deceased donor kidneys continues to outpace supply. Extended criteria donor kidneys, organs from high-risk donors, and organs after cardiac death exemplify attempts to maximize the donor pool. Kidneys from donors after cardiac death and extended-criteria now represent 33% of all kidneys

recovered (1) and could substantially increase the donor pool if used more effectively. Transplanting of horseshoe kidneys may represent another opportunity. However, its use has been documented only sporadically.

The horseshoe kidney is among the most-common of renal anatomic variations. The incidence ranges from 1 per 600-800 adults worldwide. It occurs more commonly in men than women, arising during weeks 4 to 6 of gestation by fusion of the metanephrogenic caps. It frequently contains vascular and ureteral abnormalities in addition to its fusion at the isthmus (2, 3). The isthmus connecting the lower poles may be a fibrous band, or it may contain functional parenchyma, and it is rarely, if ever, crossed by the collecting system. The vascular anatomy of the horseshoe kidney is usually complex, often involving multiple renal veins directly from the kidney as branches from the veins. The renal arteries also show great variation, with only a third of all horseshoe kidneys containing a single renal artery per side (4).

In 1522, De Carpi was the first to document a case of a horseshoe kidney (5). In the beginning of the 20th century, the frequency and clinical relevance finally became known (6). VA Politano was credited as the first person to transplant a horseshoe kidney in 1963, although this was not published (7). The kidney functioned well, but the recipient died 8 months later of hepatitis.

Horseshoe kidneys can be transplanted into a single recipient en bloc, or into 2 patients after division of the renal isthmus. Many case studies have reported technical as well as long-term effectiveness with transplant of horseshoe kidneys. No reviews, however, have been published since 2001 (8). Importantly, the use of horseshoe kidneys is not tracked by the United Network for Organ Sharing (UNOS) nor the Scientific Registry of Transplant Recipients (SRTR) databases. The purpose of this report is to provide 2 examples of

From the Departments of ¹Surgery and ²Nephrology, Albert Einstein Medical Center and the Department of ³Surgery, Hahnemann University Hospital, Philadelphia, PA, USA.

Address reprint requests to: Thomas Pontinen, MD, Albert Einstein Medical Center - Surgery
5501 Old York Road, Philadelphia, PA 19102, United States

Phone: +1 215 776 7471 Fax: +1 215 456 7706 E-mail: pont0035@umn.edu

Experimental and Clinical Transplantation (2010) 1: 74-78

successful horseshoe kidney transplants, as well as an analysis of all published cases in the literature.

One of the cases is the first known use of a horseshoe kidney procured after cardiac death. Although a recent review revealed a 24% increase in the use of organs from donors after cardiac death (1), there are no known reports of horseshoe kidneys from donors after cardiac death being transplanted.

Case Reports

A 40-year-old man, with a past medical history of hypertension, died of a gunshot wound to the head. He had no known history of urinary tract infections, kidney stones, or congenital defects. Creatinine was $88.4 \mu\text{mol/L}$ (1.0 mg/dL). At the time of death, a horseshoe kidney was identified. Vascular anatomy consisted of 4 renal arteries (1 on the left and 3 on the right), 3 renal veins (1 on the left and 2 on the right), and normal ureters and collecting systems, bilaterally. The isthmus consisted of a broad band of apparently functioning kidney tissue.

The recipient was a 63-year-old woman with end-stage renal failure, secondary to diabetes mellitus and hypertension. She had been on hemodialysis for 2 years before surgery.

On the back table, after a cold ischemia time of 14 hours, the donor kidney had irreparable damage to the right kidney's collecting duct from the procurement (Figure 1), so the kidney was divided at the isthmus (Figure 2). After separation, the left kidney, which had normal anatomy of 1 artery, 1 vein, and a single, functional ureter, was transplanted without complication (Figure 3). The raw surface was argon-beam coagulated and sealed with fibrin glue.



Figure 1. Damaged collecting duct in the discarded half of the horseshoe kidney.

Her immunosuppression consisted of induction with antithymocyte globulin (rabbit) at 5 mg/kg, tacrolimus, mycophenolate mofetil, and prednisone. She received 1 hemodialysis treatment for hyperkalemia, and 12 days after surgery, had a creatinine level of $265.2 \mu\text{mol/L}$ (3.0 mg/dL) and adequate urinary output. At 9 months' follow-up, her creatinine level was $97.2 \mu\text{mol/L}$ (1.1 mg/dL) (Figure 4).

The second case involved a 51-year-old male donor who donated a horseshoe kidney after death from suicide. At the time of admission, his serum creatinine was $141.4 \mu\text{mol/L}$ (1.6 mg/dL), and he had good urine volume.



Figure 2. Horseshoe kidney after division at the backtable.

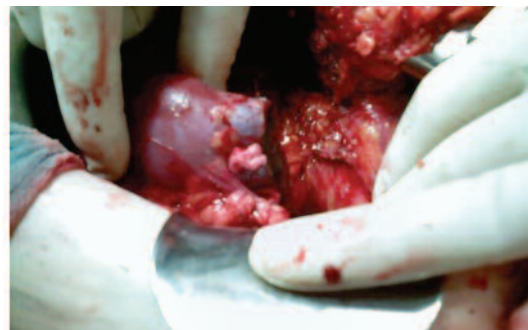


Figure 3. Horseshoe kidney after implantation into the recipient.



Figure 4. Horseshoe kidney and bladder posttransplant.

Table 1. Summary of all reported cases of horseshoe kidney transplants since 1965. (References: 9-36, 33-36)

Author (y)	Recipient age	Diagnosis	Tx kidney	Donor age	Donor creatinine	Cold time	Graft loss
Kumar 2008	43	Diabetes mellitus, HTN	Split	51	1.6	16	No
Pontinen 2008	63	Diabetes mellitus, HTN	Split	40	1.0	14	No
Salehipour 2007	NA	NA	Split	32	NA	NA	No
Salehipour 2007	NA	NA	Split	32	NA	NA	No
Dinkcan 2007	32	HTN	Split (living)	42	NA	NA	No
Dinkcan 2007	31	NA	Split	50	NA	8.5	No
Dinkcan 2007	23	NA	Split	50	NA	10	No
Corcoran 2007	63	Tacrolimus toxicity	En bloc	52	1.6	34	No
Pedro 2006	NA	NA	Split	NA	NA	NA	No
Pedro 2006	NA	NA	Split	NA	NA	NA	No
Pedro 2006	NA	NA	Split	NA	NA	NA	No
Konigsrainer 2006	54	Diabetes mellitus	Split	44	0.5	21	No
Konigsrainer 2006	44	Focal sclerosing glomerulonephritis	Split	44	0.5	25	No
Huser 2005	39	NA	Split (living)	59	NA	NA	No
Martinez 2005	NA	NA	En bloc	NA	NA	NA	No
Martinez 2005	NA	NA	En bloc	NA	NA	NA	No
Zipitis 2003	33	Reflux nephropathy	En bloc	39	NA	NA	No
Goyal 2003	NA	NA	En bloc	NA	NA	NA	No
Goyal 2003	NA	NA	En bloc	NA	NA	NA	No
Tan 2001	50	HTN	Split	35	1.1	26	No
Tan 2001	48	HTN, HUS	Split	35	1.1	32	Yes
Tan 2001	34	HTN, DM	Split	23	0.9	35	No
Tan 2001	54	HTN, DM	En bloc	39	1	30	No
Tan 2001	49	HTN	En bloc	37	1	31	No
Shen 1998	44	HTN, DM	Split	40	0.5	24	No
Shen 1998	47	Chronic glomerulonephritis	Split	40	0.5	28	No
Thomson 1997	7	Reflux	Split	58	1	NA	Yes
Thomson 1997	49	Proliferating glomerulonephritis	En bloc	3	0.4	20	No
Perumalla 1996	59	NA	Split	15	0.9	NA	No
Perumalla 1996	69	NA	Split	15	0.9	NA	No
Payen 1996	42	Glomerulonephritis	Split	33	1.1	22	No
Payen 1996	66	Idiopathic	Split	33	1.1	22	No
Botta1996	NA	NA	Split	45	<1.5	20	No
Botta1996	NA	NA	Split	45	<1.5	24	No
Botta1996	NA	NA	Split	38	<1.5	NA	No
Botta1996	NA	NA	Split	38	<1.5	NA	No
Berardinelli 1995	NA	NA	En bloc	NA	NA	NA	Yes
Berardinelli 1995	NA	NA	En bloc	NA	NA	NA	Yes
Lowell 1994	53	Diabetes mellitus	En bloc	65	1.3	22	No
White 1993	36	Diabetes mellitus	Split	22	NA	NA	No
Hayes 1993	39	FSGS	Split	23	1.2	30	No
Brenner 1990	50	HTN	En bloc	21	NA	38	No
Klan 1988	21	MPGN	En bloc	55	1.1	24	No
Vromen 1986	45	PKD	Split	14	1.1	28	No
Vromen 1986	38	Diabetes mellitus	Split	14	1.1	NA	Yes
Barry 1984	46	Chronic glomerulonephritis	Split	12	1.8	38	No
Barry 1984	51	Chronic glomerulonephritis	Split	12	1.8	46	Yes
Menezes 1981	50	NA	En bloc	29	2.2	NA	No
Majeski 1979	25	Diabetes mellitus	Split	21	1	NA	Yes
Majeski 1979	38	Chronic glomerulonephritis	Split	21	1	NA	No
Brandina 1983	46	Chronic glomerulonephritis	Split	32	NA	3	No
Brandina 1983	41	PKD	Split	32	NA	4	Yes
Nelson 1975	34	Chronic glomerulonephritis	Split	51	NA	NA	No
Nelson 1975	NA	NA	Split	NA	NA	NA	Yes
Nelson 1975	29	Chronic glomerulonephritis	Split	51	NA	NA	No

Abbreviation: PKD, polycystic kidney disease; NA, nonapplicable; FSGS, focal segmental glomerulosclerosis; HTN, hypertension; MPGN, membranoproliferative glomerulonephritis; HUS, hemolytic-uremic syndrome; Tx, transplanted.

The recipient was a 43-year-old woman, with end-stage renal disease due to diabetes mellitus and hypertension. She was on maintenance hemodialysis from September 2005 until the time of surgery.

At the back table, the horseshoe kidney was divided at the bridge, and the left half was used. It was divided because it was too large to be transplanted en bloc. The first half was transplanted, but the second half could not be used because a suitable recipient

could not be found in time. The transplanted kidney had 2 arteries, a single vein, and a single ureter. Cold ischemic time was 16 hours.

Her immunosuppression consisted of basiliximab, tacrolimus, and mycophenolic acid. She required 1 round of dialysis after surgery for hyperkalemia. She is currently doing well, with a continually falling creatinine of 194.4 $\mu\text{mol/L}$ (2.2 mg/dL) at 5 months follow-up.

Discussion

A MEDLINE search revealed 28 case reports of horseshoe kidney transplants, published between 1965 and 2008 (Table 1). Sixteen horseshoe kidneys were divided and transplanted into 32 recipients. Three horseshoe kidneys were transplanted into 3 recipients after division, because vascular anomalies led to discarding them.

Fifteen horseshoe kidneys were transplanted en bloc into 15 recipients. Of the 34 horseshoe kidneys divided and transplanted into 50 recipients, 15 recipients received en bloc kidney (44%), and 19 received a split kidney (56%). The average age of the recipients and donors was 44.3 years (range, 7-69 years) and 34.4 years (range, 3-65 years). Average cold ischemic time was 24.4 hours, (range, 3-46 hours). Nine grafts (18%) (2 en bloc and 7 split) experienced primary nonfunction at follow-up. Forty-one transplanted kidney allografts (82%) demonstrated good function at a median follow-up of 6 months. There were 2 recipient deaths. Twenty-one recipients (42%) were followed for at least 1 year after the transplant, all were reported to have good kidney function. Despite the high incidence of complex vascular anomalies, there was only 1 case (2%) of intraoperative vascular thrombosis.

The literature review did not reveal any reported cases of a horseshoe kidney being transplanted from a donor after cardiac death. There were 3 case reports of living-donor horseshoe kidney transplants. In each incidence, the horseshoe kidney was split, and transplanted in a single recipient. All 6 of these patients (both donor and recipients) demonstrated excellent function at their respective follow-ups.

The number of patients awaiting a transplant continues to rise. As of April 2009, there were 75 000 wait list candidates on UNOS. Organs previously deemed unacceptable for transplant are being used with increased regularity, exposing surgeons to new technical and ethical challenges (8, 32, 37). Horseshoe kidneys represent 1 of these challenges. Case reports have been published on techniques and outcomes. Almost all of them have reported good results, if careful attention is paid to the anatomic variations. For example, renal vessels often originate from the iliac arteries and veins, while the renal isthmus can have an independent blood supply. Attempts have been made to classify the vascular anatomy, (38, 39) but the complexity has made this challenging. Results from transplanted horseshoe kidneys appear to be similar

to those of nonhorseshoe kidneys. However, there may be a reporting bias.

In addition to a complex anatomy, horseshoe kidneys pose another obstacle to widespread acceptance. Neither UNOS nor SRTR has specific data on horseshoe kidneys in their databases. Several literature reviews have been published, with several European studies, but the majority of publications are only letters or case reports, which make it challenging to obtain clinically relevant data. It is possible that the lack of experience and knowledge may have lead to the discarding of the second kidney in donors after cardiac death. We recommend that horseshoe kidney transplants be included in the database in the hope that transplant surgeons will become more comfortable with their use.

Horseshoe kidneys from donors after cardiac death also may provide a potential addition to the donor pool. It has been estimated that the number of transplantable kidneys may increase by 25% or more with the aggressive implementation of donors after cardiac death protocols (40). The risk of rejection, as well as technical complications, is the same as DND (Donation after Neurological Death) kidneys (41). Coupled with emerging data on horseshoe kidneys, donors after cardiac death could provide a valuable resource for the donor pool.

In conclusion, many studies have already shown that kidney graft survival from donors after cardiac death is equivalent to that from brain-dead donors (42), and that short-term and long-term patient and graft survival after cardiac-death donor transplants are equivalent to those of donors after DND kidneys (43). Horseshoe kidneys appear to be a reliable source of organs for transplant and should be used with confidence on a regular basis. We recommend that kidneys from donors after cardiac death, horseshoe kidneys, and horseshoe kidneys from donors after cardiac death should all be used as a source of organs for transplant, and their data is tracked accurately in the UNOS database.

References

1. Tuttle-Newall JE, Krishnan SM, Levy MF, McBride V, Orlowski JP, Sung R. Organ donation and utilization in the United States 1998-2007. *Am J Transplantation*. 2009;9(part 2):879-893.
2. Bauer SB. Anomalies of the kidney and ureteropelvic junction. In Walsh PC, Retik AB, Vaughan ED, Jr. et al., eds. *Campbell's Urology*. 7th ed. Philadelphia, PA: WB Saunders; 1998:1708.
3. Ratner LE, Zibari G. Strategies for the successful transplantation of the horseshoe kidney. *J Urol*. 1993;150(3):958-960.

4. Perlmutter AD, Retik AB, Bauer SB. Anomalies of the urinary tract. In *Campbell's Urology*. 5th ed. Philadelphia, PA: WB Saunders; 1986:1686.
5. Berenger DA Carpi. Isagogae breves perlucide ac uberrime in anatomiam humani corporis. Bologna, Woodcut. National Library of Medicine, 1535
6. Farman F. Fusion anomalies of the kidney. In Alken CE, Dix VW, Goodwin WE, Weyrauch HM, Wildbolz E, eds. *Encyclopedia of Urology*. New York, NY: Springer-Verlag; 1968:66.
7. Nelson RP, Palmer JM. Use of horseshoe kidney in renal transplantation: technical aspects. *Urology*. 1975;6:357-359.
8. Stroosma OB, Scheltinga MRM, Stubenitsky BM, Kootstra G. Horseshoe kidney transplantation: an overview. *Clin Transpl* 2000;14:515.
9. Tan HP, Samaniego MD, Montgomery RA, et al. Donor horseshoe kidneys for transplantation. *Transplantation*. 2001;72(5):869-873.
10. Thomson BN, Francis DM, Millar RJ. Transplantation of adult and pediatric horseshoe kidneys. *Aust NZ J Surg*. 1997;67:279-282.
11. Perumalla C, Lawen JG, Macdonald AS. Transplantation of a horseshoe kidney into two recipients after separation. *Br J Urol*. 1996;78:145-146.
12. Payen E, Bretheau D, Lechevallier E, Berland Y, Olmer M, Coulange C. Transplantation of a horseshoe kidney into 2 recipients. *Urol Int*. 1996;56:107-109.
13. Botta GC, Capocasale E, Mazzoni MP. Transplantation of horseshoe kidneys: a report of four cases. *Br J Urol*. 1996;78:181-182.
14. Berardinelli L, Raiteri M, Constantino B. Safe utilization and long-term follow-up of 368 marginal kidneys. *Transplant Proc*. 1995;27:3446-3447.
15. Lowell JA, Taylor RJ, Cattral M, Bynon JS, Brennan DC, Stratta RJ. "En bloc" transplantation of a horseshoe kidney from a high risk multi-organ donor: case report and review of the literature. *J Urol*. 1994;152:468-470.
16. White JC, Shaver TR, Kocandir V. Simultaneous kidney-pancreas transplantation using a horseshoe kidney. *Transpl Int*. 1993;6:302-303.
17. Hayes JM. The transplantation of difficult donor kidneys and recipients: helpful surgical techniques. *J Urol*. 1993;148:250-254.
18. Brenner DW, Schlossberg SM, Hurwitz RL. Transplantation of horseshoe kidney into single recipient. *Urology*. 1990;35:530-532.
19. Klan R, Hirner A, Fiedler U, Offermann G. Transplantation of a horseshoe kidney "en bloc": report of a case. *J Urol*. 1988;139:571-572.
20. Vromen MA, Van der Vliet JA, Ruers TJ, Muller GH, Kootstra G. Use of horseshoe kidneys for transplantation. *Neth J Surg*. 1986;38:183-186.
21. Barry JM, Fincher RD. Transplantation of a horseshoe kidney into 2 recipients. *J Urol*. 1984;131:1162-1163.
22. Menezes de Goes G, De Campos Freire G, Borrelli M, Pompeo AC, Wroclawski ER. Transplantation of a horseshoe kidney. *J Urol*. 1981;126:537-538.
23. Majeski JA, Alexander JW, First R, Munda R, Fidler JP. Transplantation of a horseshoe kidney. *JAMA*. 1979;242:1066.
24. Brandina L, Fraga AM, Bergonse MR, et al. Kidney transplantation: the use of abnormal kidneys. *Nephron*. 1983;35:78-81.
25. Nelson RP, Palmer JM. Use of horseshoe kidney in renal transplantation: technical aspects. *Urology*. 1975;6:357-359.
26. Nahas WC, Hakim NS, Mazzucchi E, et al. Transplantation of horseshoe kidney en bloc. *Int Surg*. 2000;85(3):272-274.
27. Goyal A, Gaitonde K, Sagade SN, Shah BV, Kamat MH. Transplantation of horseshoe kidney from living-related donors: report of two cases. *Transplant Proc*. 2003;35(1):32-34.
28. Martínez-Mier G, Rayhilloye SC. Cadaveric kidney transplant using horseshoe kidney: report of two cases. *Cir Cir*. 2005;73(3):211-216.
29. Hüser N, Gerauer KE, Novotny AR, Assfalg V, Stangl MJ. Successful living donor transplantation of a kidney with horseshoe malformation: extending the donor pool. *Transpl Int*. 2005;18(6):761-762.
30. Königsrainer I, Knubben K, Thiel C, Steurer W, Königsrainer A. Successful transplantation to two recipients after splitting a large horseshoe kidney with complicated anatomy. *Transpl Int*. 2006;19(6):521-522.
31. Zipitis CS, Augustine T, Tavakoli A, Surange R, Agrawal A, Riad HN. Horseshoe kidney transplantation. *Surgeon*. 2003;1:160-163.
32. Stroosma OB, Shurink H. Transplanting horseshoe kidneys: a worldwide survey. *J Urol*. 2001;166:2039-2042.
33. Dinckan A, Tekin A, Turkyilmaz S, et al. Horseshoe kidney for transplant: report of 3 cases. *Exp Clin Transplant*. 2007;5(2):716-719.
34. Corcoran A, Shapiro R, Kayler L. Transplantation of a horseshoe kidney. *Transplantation*. 2007;83:828-829.
35. Salehipour M, Bahador A, Salahi H, et al. Transplantation of a horseshoe kidney. *Arch Iran Med*. 2007;10(2):239-241.
36. Pedro RN, Leitao V, Myiaoka R. Split technique in horseshoe kidney transplantation. *Urol Int*. 2006;77:6-8.
37. Uzzo RG, Hsu TH, Novick AC, Gill IS. Strategies for transplantation of cadaveric kidneys with congenital fusion anomalies. *J Urol*. 2001;165:761-765.
38. Graves FT. The arterial anatomy of the congenitally abnormal kidney. *Br J Surg*. 1969;56(7):533-541.
39. Boatman DL, Cornell SH, Kölln CP. The arterial supply of horseshoe kidneys. *Am J Roentgenol Radium Ther Nucl Med*. 1971;113(3):447-451.
40. Kootstra G, Kievet J, Nederstigt A. Organ donors: heartbeating and nonheartbeating. *World J Surg*. 2002;26:181-184.
41. Cooper JT, Chin LT, Krieger NR, et al. Donation after cardiac death: the university of Wisconsin experience with renal transplantation. *Am J Transplant*. 2004;4(9):1490-1494.
42. Doshi MD, Hunsicker LG. Short and long term outcomes with the use of kidney and livers donated after cardiac death. *Am J Transplant*. 2007;7:122-129.
43. Farney AC, Singh RP, Hines MH, et al. Experience in renal and extrarenal transplantation with donation after cardiac death donors with selective use of extracorporeal support. *J Am Coll Surg*. 2008;206(5):1028-1037; discussion 1037.