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Evaluating the differences in the early laparoscopic donor nephrectomy learning curves of a Swiss high volume transplant program and a South African low volume transplant program after knowledge transfer

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Abstract

Background: To describe the retroperitoneoscopic donor nephrectomy learning curve differences between a high volume (training) hospital in Basel, Switzerland, and a low volume (trainee) hospital in Cape Town, South Africa, after knowledge transfer. The South African hospital is resource constraint in hospital and training equipment. Techniques for performing the surgery were near identical.

Methods: Both units maintained prospective databases. Comparisons were made of the first 74 cases in each database: Basel's series were from 19 January 2001 until 28 June 2004, while the Cape Town Hospital were from 8 April 2008 until 15 July 2008. Four surgeons operated in the Basel group, while only one surgeon operated in the Cape Town group. Variables compared include operating time (first skin incision until kidney was extracted), warm ischaemic time (renal arterial occlusion until cold bench reperfusion), blood loss, graft function, and hospital stay. We also analysed the first and last 25 cases of each series. Subgroup analysis of a single Basel surgeon was conducted.

Results: Donor age (means: Basel vs. Cape Town 54 vs. 33 $p < 0.0001$) and gender (males vs. females Cape Town 57% male and Basel 31% male) differed widely. The Basel group did more left-sided operations (72% vs. 58%). Operative times, blood loss and donor creatinine did not differ. Warm ischaemic time was significantly shorter in the Basel group (Cape Town mean 204 s Basel mean 130 s $P = 0.0023$). There was double the number of early graft failures in the South African group (six vs. three)—not related to donor surgery. Both groups showed a decline in operating times, plateauing at 30–34 cases.

Conclusions: There are statistically significant differences in some aspects of the learning curves of the Swiss (training) and South African (trainee) hospitals. These differences are clinically not pronounced, and the knowledge transfer was worth the effort.

Keywords: Donor nephrectomy, Minimal access donor nephrectomy, Learning curve, Comparison of learning curve

1 Background

Donor nephrectomy is a high-stakes operation which requires good surgical skills and patient care to accomplish safe and non-fatal outcomes for the donor and the recipient [1]. Minimal access donor nephrectomy

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has been shown to increase the willingness of potential donors to donate kidneys [2]. However, the South African hospital studied (Tygerberg Academic Hospital, Cape Town) lacked some of the necessary skill and training infrastructure to start a laparoscopic donor program on site. Virtual trainers [3], dry laboratory trainers, or tele-mentoring [4] might be successfully used to increase skill and decrease the learning curve prior to operating on patients. These tools are useful in the era of reduced working hours and increased litigation—however, they were not available in the South African unit at the time of starting the donor nephrectomy program.

The use and evolution from porcine models to human patients for performing laparoscopic donor nephrectomy have been used with success to reduce operating time and blood loss [5, 6]. After the Tygerberg group operated on a series of pigs for a laparoscopic partial nephrectomy study [7], we argued that pigs did not simulate the real-life situation well enough (being too easy to operate on), and thereby creating a false sense of security. As we were versed in retroperitoneoscopic simple and radical nephrectomy, we used the additional steps of initial total hilum dissection and then hand extraction (as opposed to hand-assisted). We therefore wanted to investigate the differences in the learning curves between the “trainee” hospital in South Africa and the “training” hospital in Switzerland to see how different training platforms on the two continents affected the learning curves. Donor safety at Tygerberg Hospital has been established after 50 cases [8]; however, more cases were evaluated to exclude potential bias at 50 patients.

2 Methods

This is a retrospective database study of the first consecutive 74 cases in each arm. Both centres maintain donor nephrectomy databases prospectively. The setting of the Swiss centre (Basel) and South African (Cape Town) centre is in academic hospitals servicing a wider community. Donors were selected from family members willing or philanthropists to donate their kidney.

Basel's series were from 19 January 2001 until 28 June 2004, while the Cape Town Hospital were from 8 April 2008 until 15 July 2008. The surgeons in each centre were consultants. The surgeon in Cape Town was versed in retroperitoneoscopic simple nephrectomy after three years of training. The surgeons in the Basel group were versed in all types of retroperitoneoscopic surgery, including donor nephrectomy, which was attempted first after two years of training.

The surgical technique of donor nephrectomy in both hospitals is a flank position similar to open nephrectomy—making the conversion to open surgery if needed, feasible and swift. Three- or four-port retroperitoneal

access is created with an inflation balloon. The hilum is completely dissected to remove all peri-vascular tissue prior to fully mobilizing the kidney from the peri-nephric fat and transecting the ureter. Once the kidney is completely mobilized, a hand for hand extraction is placed via a muscle-splitting incision of 6–7 cm in the bikini line on the ipsilateral side. Vessel occlusion and transection, after hand insertion, were done with the use of a vascular stapling device in the Basel group and with extra-large, locking, non-transfixing, nylon vascular clips in the South African group.

We defined the learning curve of minimal access donor nephrectomy as consisting of the elements of operating time, blood loss, warm ischaemic time, hospital stay, complications and graft function. No index exists combining these values; therefore, we decided to report on each variable separately. Both groups made use of a prospectively collected database to collect donor data of 148 cases—74 in each group. Data collected include donor demographics, operating time, warm ischemic time (both time-based variables), blood loss, side of surgery (performance-based variable), gender, rank in series, donor and recipient renal function, complications, and hospital stay (safety variables). These variables were compared in the first 74 cases of each series. The Swiss group had four surgeons participating in the series and the South African group only one; therefore, the surgeon who started the retroperitoneoscopic donor operations and did the most cases in the Swiss series was analysed as a subgroup and compared with the single South African surgeon. Also, the first and last 25 cases in each series were analysed.

Prior to processing the data, the identity of patients was replaced by case numbers to ensure confidentiality. The Human Research Ethics Committee reviewed the protocol, including the methodology and statistical methods to be employed, and approval was obtained under the number S14/02/047. For variables that are not continuous, descriptive statistics were used. Because some of the elements of the learning curve (as defined by us) are continuous variables, the means and the difference in means were calculated. For each difference in means, a *p*-value and 95% confidence interval were calculated using an unpaired two-tailed *t* test (Student's *t* test). A *p*-value of less than 0.05 was chosen to indicate a statistically significant difference in means. However, clinical significance was not automatically inferred from this.

3 Results

The mean age of the groups differed significantly (33 years in the Tygerberg group and 54 years in the Basel group: Table 1). The gender differed significantly between the two groups (57% males in the Tygerberg group and 31% males in the Basel group). The Basel group did more

Table 1 Comparative results of renal donor operations at Basel University Hospital Switzerland and Tygerberg Academic Hospital South Africa

	Tygerberg 74 cases	Basel 74 cases	Mean difference	P—value	95% CI
Age in years—mean (range)	33 (18–52)	54 (27–79)	21	<0.0001	17.8–24.3
Body mass index (BMI) m ² /kg—mean (range)	26.4 (17–39)	25.8 (17.3–40.1)	2.1	0.39	2.1–0.8
Males/females (% male)	42/32 (57%)	23/51 (31%)			
Left/right (%left)	43/31 (58%)	49/19 (72%)			
Time to complete series	75 months	32 months			
Operative time in minutes—mean (range)	148 (75–255)	152 (60–270)	– 4	0.658	– 11.7–18.6
Blood loss in millilitre—mean (range)	134 (5–700)	170 (0–600)	– 36	0.0845	– 5.0–77.5
Warm ischaemic time in seconds—mean (range)	187 (105–630)	120 (50–240)	67	<0.0001	– 44.6–90.1
Warm ischaemic time left in seconds—mean (range)	162 (105–330)	120.6 (50–240)	41.4	0.0002	21 – 63.8
Warm ischaemic time right in seconds—mean (range)	222.4 (120–630)	118.4 (60–180)	104	0.0003	50.8–157.1
Intra-department warm ischaemic time left vs. right Basel—difference in means in seconds		2.2	2.2	0.75	– 26.1–18.8
Intra-department warm ischaemic time left vs. right Tygerberg—difference in means in seconds	60.4		60.4	0.001	26.9–101.8
Hospital stay in days—mean (range)	3.8 (2–8)	11 (4–29)	– 7.2	<0.0001	6.4–8.1
Donor creatinine at six months mmol/l—mean (range)	100 (60–135)	105 (73–159)	– 5	0.85	– 8.7–10.4
Graft failure at six months	6	3			
Recipient serum creatinine excluding above cases mmol/l—mean (range)	162 (64–353)	na			
Donor deaths	0	0			
Conversions	1	2			
	Tygerberg first 25 cases	Basel first 25 cases	Mean difference	P value	95% CI
Operative time in minutes—mean (range)	171.8 (90–250)	158.8 (90–270)	13	0.34	– 14.7–41.3
Blood loss in millilitre—mean (range)	144 (5–700)	179 (50–500)	– 35	0.41	– 51.2–121.8
Warm ischaemic time in seconds—mean (range)	204 (107–630)	130 (60–240)	74	0.0023	28–120.6
Blood transfusions in units	0	3			
Conversions	0	2			
	Tygerberg last 25 cases	Basel last 25 cases	Mean difference	P value	95% CI
Operative time in minutes—mean (range)	144 (85–255)	144 (70–210)	0	0.98	– 24.9–24.4
Blood loss in millilitre—mean (range)	122 (15–375)	150 (0–600)	– 28	0.4	– 38.5–94
Warm ischaemic time in seconds—mean (range)	201 (105–540)	117 (65–230)	84	0.0001	43.7–126.5
Blood transfusions in units	0	0			
Conversions	0	0			
	Tygerberg single surgeon	Basel single surgeon (AB)	Mean difference	P value	95% CI
Operative time in minutes—mean (range)	148 (75–255)	154 (70–270)	– 6	0.56	– 13.7–25.08
Blood loss in millilitre—mean (range)	134 (95–700)	188 (0–600)	– 54	0.55	– 1.34–110.3
Warm ischaemic time in seconds—mean (range)	187 (105–630)	124 (90–230)	63	<0.0001	39.7–86.1
Conversions	0	0			
Blood transfusions in units	0	0			

left-sided operations (72% vs. 58%). The Tygerberg group took more than double the time to complete their series (75 months vs. 32 months). Operative times, blood loss, and donor creatinine post-operatively did not differ. Warm ischaemic times were significantly shorter in the Basel group ($p < 0.0001$). Recipient creatinine was not

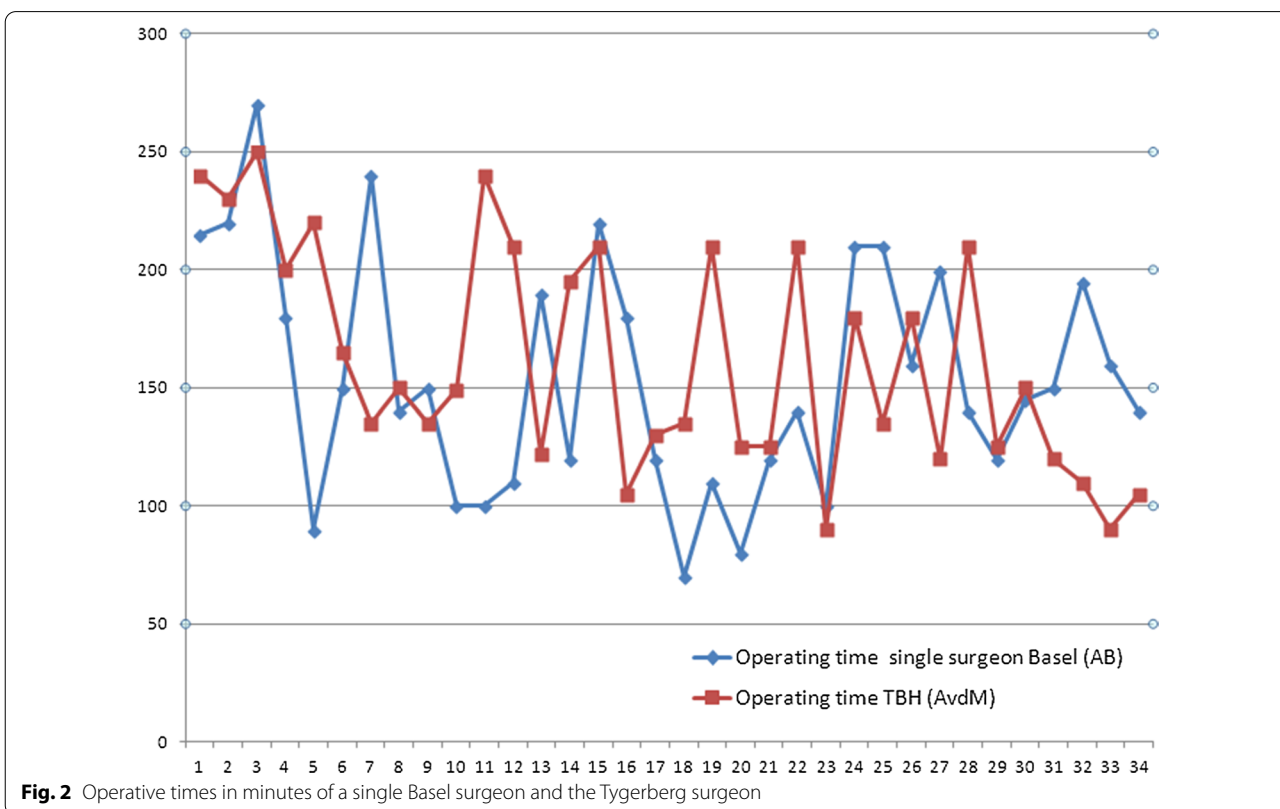
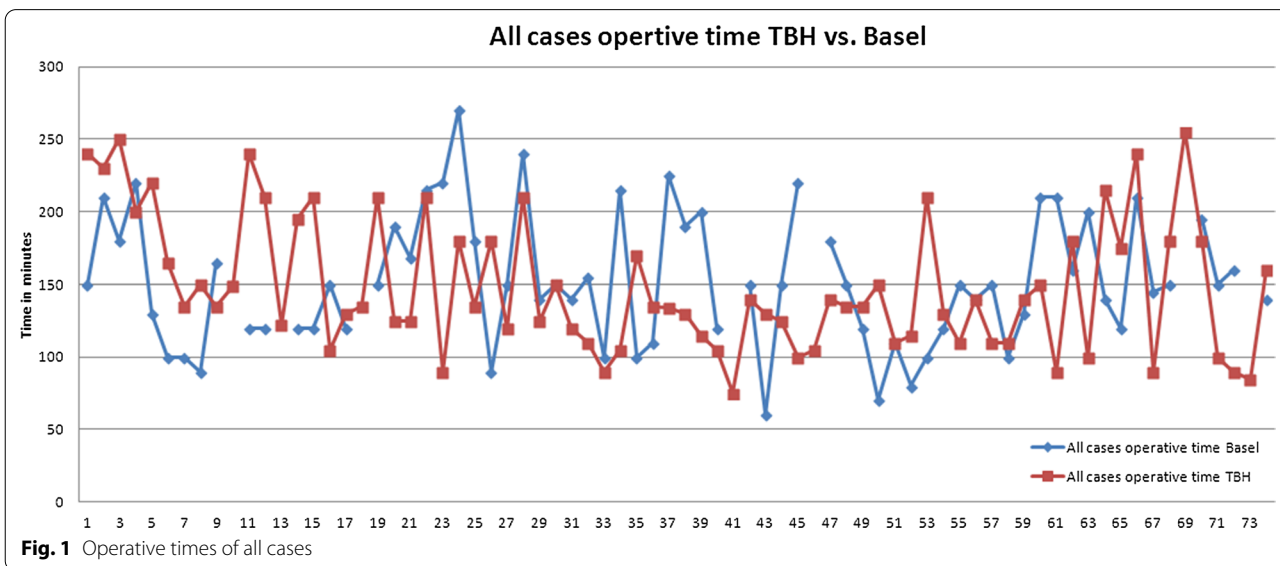
available in the database for the Basel group but was similar to their previous report [9]. Graft failures were double in the Tygerberg group (six vs. three). No donor deaths occurred in either group.

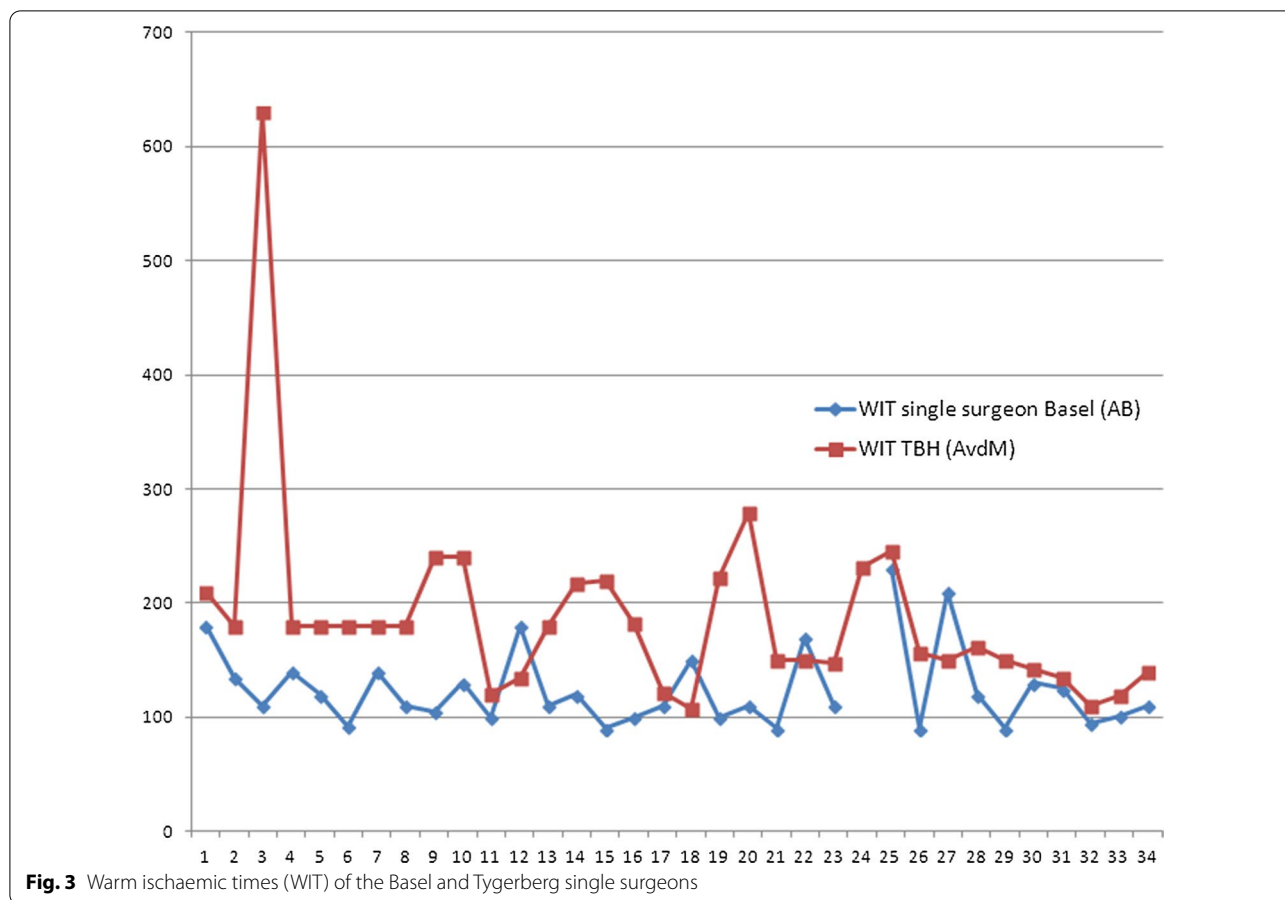
There was one conversion in the Tygerberg group (indication renal torsion) and two in the Basel group

(indications bleeding and diaphragm injury). In the Tygerberg group, right-sided nephrectomies had significantly longer warm ischaemic times compare to left-sided nephrectomies. This was not evident in the Basel group. Both hospitals showed a decline in the operating time, blood loss, and warm ischaemic time in their own

series between the first and last 25 cases. When comparing the hospitals' warm ischaemic times, it was found that they were significantly shorter in the Basel group in the first and last 25 cases (Figs. 1, 2, 3).

As a subgroup, comparing a single surgeon from the Basel group (who was taught donor nephrectomy by his





experienced mentors) to the Tygerberg group, all variables showed a similar pattern to the results above—also with shorter warm ischaemic times in the Basel surgeon’s series.

Both groups reported four complications (5.4%). The Tygerberg group’s right-side donor kidneys had three cases of a short renal vein, requiring deep femoral vein harvesting from the recipient prior to implantation (Table 2). One such recipient had mild swelling of the leg and had to use compression

stockings post-operatively—this subsequently settled. None of the recipients developed renal vein thrombosis, nor did they develop deep vein thrombosis. One Tygerberg donor developed an incisional hernia at the extraction site. One Basel patient developed a myocardial ischaemic event post-operatively. Another needed re-operation after a major vascular injury, one thoracic duct injury required re-operation, and another were re-operated after diaphragmatic rupture from the inflation balloon.

Table 2 Major complications needing intervention: number (%)

Complication	Tygerberg 74 cases	Basel 74 cases
Short right renal vein needing vein graft	3 (4.1%)	0 (0%)
Myocardial infarction	0 (0%)	1 (1.4%)
Incisional hernia at extraction site	1 (1.4%)	0 (0%)
Diaphragmatic rupture	0 (0%)	1 (1.4%)
Aortic injury	0 (0%)	1 (1.4%)
Ductus thoracicus injury	0 (0%)	1 (1.4%)

4 Discussion

It is not easy to define the exact meaning of the “learning curve” in any surgery type [10, 11]. The Merriam-Webster dictionary defines it as “the course of progress made in learning something” [12]. Learning curves in surgery have been denied [13], respected [14, 15] and even said to last up to 26 years [16].

Retroperitoneoscopic donor nephrectomy is not an easy operation to learn, as is evident by the initial report from a centre of excellence with an average operative time of 280 min [17]. This might be due to the reduced working space, especially at the start of surgery. Learning this procedure in a centre of excellence is different from learning to perform it in a resource-poor environment, having only distance contact with the training hospital for most of the series.

Differences in donor demographics, which is evident in our study, might play a role in the donor nephrectomy learning curve operating variables [18]. The proportion of males in the Tygerberg group (57%) was significantly more than the proportion of males in the Basel group (31%). The Basel group’s gender distribution is more similar to the American donors [19] (41% males) and the Japanese donors [20] (33% males). There seems to be no clear explanation as to why males in the South African hospital are more willing to donate their kidneys than females.

The low case volume of the Tygerberg group is evident, as the Tygerberg group took more than twice as long to reach 74 cases. Even though the low case volume is a concern, Todokai et al. report on the safety of a low case volume series of retroperitoneoscopic donor nephrectomy with the learning curve improving at around 30 cases [21].

The operative times declined in both series according to statistical analysis, but this is not graphically evident in the Basel series if all cases and all operating surgeons are included, as demonstrated in Fig. 1. However, in Fig. 2, where the subgroup of a single Basel surgeon’s 34 cases is compared to 34 cases in the Tygerberg group series, a similar decline in operating time curves is seen. Both the operating times and warm ischaemic times seem to improve maximally at about 30–34 cases in the single surgeon comparison, as seen in Fig. 3.

Graft failures were double in the Tygerberg group, which may be explained by differences in the recipient profile. In the Tygerberg group, potential recipients present late in renal failure, and vascular access surgery for dialysis has a long waiting list. This has the effect that temporary dialysis lines are often placed in the femoral vessels, making transplant surgery difficult due to the formation of synechia, thrombosis and peri-vascular inflammation. During this series, three surgeons started doing renal transplantation at the Tygerberg group that possibly created a double learning curve for renal transplantation

affecting graft outcomes. However, the learning curve of the donor operations might still have contributed to the high number of graft failures despite all procured kidneys being deemed suitable for transplantation. None of the kidneys needing a profunda femoris vein graft died.

The three short renal veins needing vein grafting and vein interposition probably relate to the large number of right-sided donors in the Tygerberg series, as well as the emphasis on donor safety using locking vascular clips with a good cuff of vein and artery. Any form of clip is controversial to control the vascular pedicle [1]. The Tygerberg group does not use any vessel-sealing device in hilar dissection due to budget constraints. Small titanium or nylon clips are applied to control potential bleeders around the pedicle, for example, when crossing lumbar, gonadal, and adrenal veins. In the presence of these clips, it becomes an unacceptable risk to use vascular staplers on the renal vein and renal artery due to potential stapler failure. Albeit controversial, locking vascular clips are established as a safe method of controlling the donor renal artery and renal vein [22, 23].

The longer warm ischaemic time for right-sided operations in the Tygerberg series is interesting and might indicate that more time is needed to occlude the short renal vein with the used method of occlusion, which is not as accessible on the right as compared to the left. There is no difference in the right and left warm ischaemic times using a stapler device in the Basel group, as well as the subgroup of a single Basel surgeon. This could either be related to individual surgeon aptitude [24], dexterity, and high volume laparoscopic surgery—or it could possibly be due to the near perfect training facilities in Basel, Switzerland, compared to the less than desired laparoscopic training facilities at Tygerberg, South Africa. Using video motion analysis, if available, might detect dexterity-related problems and help improve dexterity [25]. Using animal models could be a good training model for laparoscopic donor nephrectomy [14, 26], but the Tygerberg group argues that it might create false reassurance.

There were more major donor complications in the Basel group. One Basel donor developed a myocardial infarction post-operatively, another suffered a major vascular injury needing re-operation, and a diaphragmatic injury was reported during their learning curve. The lack of major donor morbidities in the Tygerberg group might result from increased caution as backup for this procedure being lacking; conversion to open surgery was the only option if any problems would arise.

Figure 4 demonstrates a right-sided nephrectomy using the (potentially less dexterous) left hand to clip the renal vessels. A other South African group who reported an animal model to reduce the effects on their learning curve of laparoscopic donor nephrectomy [14] later reported a donor death in their initial cases performed [27]. This South African donor death might indicate a health system failure



Fig. 4 Hand extraction prior to vessel clipping of a simple nephrectomy similar to donor nephrectomy is excellent training for donor nephrectomy. This operation by the two surgeons was part of the knowledge transfer process and was in Dakar, Senegal, as part of a workshop

(in addition to the surgical learning curve in a resource-constrained environment) because the bleeding donor could not be prioritized back to the theatre despite every possible effort from the surgical team to do that. We believe that animal models should not be a part of donor nephrectomy training as surgeons should be proficient enough at renal surgery not to need such a model. The complexity and high stakes of donor surgery should not be underestimated.

Proficiency is defined as the point where the slope of operative variables becomes less steep [10]—in both groups, this is around 30–34 cases (Figs. 1, 2). A second plateau in donor nephrectomies might exist after about 300 cases [28]. Interestingly, there might be a shorter learning curve for more senior surgeons [29], or complications might worsen after the age of 45 [30]. The surgeons' ages were not documented in this report; however, surgeons were of approximately similar “young” age—below 45 years old. If the hospital's total laparoscopic program is of low volume, in addition to the low volume donor program, it might affect the learning curve even more: It appears that after about every 50 cases performed, there are improvements in surgical skill, at least as applied to radical prostatectomy [31].

The more prolonged hospital stay in the Basel group is related to cultural differences and less pressure on inpatient beds.

One of the limitations of this study is that the graft creatinine was not available for one group in this database and had to be compared with a previous report [9]. To use observational data to comment regarding surgical outcomes

has limited value as causality cannot be automatically inferred. Because the focus of this paper was on comparison rather than individual analysis of either group's learning curve, the Basel group's learning curve has not been evaluated in such detail as the Tygerberg group's learning curve. It is challenging to make comparisons when the circumstances, resources, patients, and skills profiles of the two units are so different.

5 Conclusions

There are significant differences between the two donor nephrectomy learning curves in terms of time-based, performance-based, and safety based variables of the Swiss (training) and South African (trainee) hospitals. More graft losses in the South Africa group were not related to clear donor surgery-related events. Clinically, the differences are less obvious, and donor safety is confirmed in the trainee hospital learning curve. Knowledge transfer from the Swiss to the South African hospital was possible with the model used, although not ideal.

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Authors' contributions

AvdM was responsible for the South African data collection and writing up of the manuscript; NEM was responsible for the Swiss data collection and writing up of the manuscript; GB assisted with the Swiss data collection and writing up of the manuscript; HvD assisted with the writing up of the manuscript; GM assisted with the writing up of the manuscript; HvH assisted with the data collection and writing up of the manuscript; ZK assisted with the data collection and writing up of the manuscript; AB assisted with the data collection and writing up of the manuscript. All authors have read and approved the final manuscript.

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Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The Human Research Ethics Committee reviewed the protocol, including the methodology and statistical methods to be employed, and approval was obtained under the number S14/02/047. Patients signed informed consent for the procedure.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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