TURKISH JOURNAL OF UROLOGY
Turkish Journal of Urology 2012; 38(2): 74-79 • doi:10.5152/tud.2012.018
ENDOUROLOGY
Original Article

The use of anatomical landmarks for percutaneous nephrolithotomy

Perkütan nefrolitotomide anatomik göstergelerin kullanımı

Esat Kaan Akbay[1], Burak Turna[2], Servet Çelik[3], Emil Mukhtarov[2], Ahmet Barış Altay[2], Oktay Nazlı[2]

ABSTRACT

Objective: The aim of our study was to describe the external anatomical landmarks and angles as a training guide for urologists in the performance of percutaneous nephrolithotomy (PCNL) in the prone position.

Materials and Methods: Between 2006 and 2008, 50 patients (including 10 resident cases) undergoing PCNL met the study criteria. The inclusion criteria consisted of patients with renal stones scheduled for a lower calyceal puncture PCNL where the number of attempts to access the calyx ≤ 3, and clear urine was seen draining from the needle. The exclusion criteria consisted of previous ipsilateral kidney surgery, severe hydronephrosis, anomalies of the renal or skeletal systems, BMI>30 kg/m^2, upper/middle calyceal puncture and age ≤18. Several anatomical landmarks and angles were measured, recorded and analyzed.

Results: The mean length of (Pi) was 10.1±1.7 cm (range 7-14), (Pe) was 9.9±1.7 cm (range 6-13), (a) was 11.2±2.8 cm (range 5.5-17), (b) was 5.3±2.3 cm (range 1.5-11 cm), (x) was 5.1±1.9 cm (range 1-8), (x1) was 3.3±1.7 cm (range 1.5-8.2), (y) was 7.1±1.7 cm (range 3.3-11.6), (y1) was 3.8±1.6 cm (range 1-9) and (t) was 4.9±1.7 cm (range 3-9). The mean angle for (α) was 49±13° (range 30-70°), (β) was 41±13° (range 20-70°) and (γ) was 61±13° (range 28-80°). In resident cases, the median number of attempts was 1 (range 1-3), the median overall time for successful access was 7.25 minutes (range 2-12) and the median fl uoroscopy time was 62.5 seconds (range 30-150).

Conclusion: A knowledge of these anatomical landmarks and angles may increase the capacity of urologists to repetitively perform the precise task of percutaneous access of the lower calyceal during PCNL.

Key words: Access; anatomy; kidney; percutaneous nephrolithotomy; urolithiasis.

ÖZET

Amaç: Çalışmamızda prone pozisyonunda uygulanan perkütan nefrolitotomide dış gösterge ve açıların tanımlanması amaçlanmıştır.

Gereç ve Yöntem: Çalışmaya alınma kriterlerine uygun 50 (10 asistan vakası dahil) hasta 2006-2008 arasında çalışmaya dahil edildi. Çalışmaya alınma kriterleri, alt kalikse 3 ve daha az girişimde başarılı olunması ve iğneden berrak idrar gelmesi; dışlanma kriterleri ise aynı taraftan geçirilmiş operasyon, ciddi hidronefroz, böbrek veya iskelet anomalileri, obezite, orta-üst kaliks girişimi gerektiren hastalar ve 18 yaşından küçük hastalar olarak belirlendi. Çeşitli anatomik göstergeler ölçülüp değerlendirildi.

Bulgular: Anatomik göstergelerden ortalama değerler şu şekilde saptandı; (Pi) 10.1±1.7 cm (7-14), (Pe) 9.9±1.7 cm (6-13), (a) 11.2±2.8 cm (5.5-17), (b) 5.3±2.3 cm (1.5-11 cm), (x) 5.1±1.9 cm (1-8), (x1) 3.3±1.7 cm (1.5-8.2), (y) 7.1±1.7 cm (3.3-11.6), (y1) 3.8±1.6 cm (1-9) ve (t) 4.9±1.7 cm (3-9). Anatomik açıların değerleri ise; (α) 49±13° (30-70°), (β) 41±13° (20-70°) ve (γ) 61±13° (28-80°) olarak ölçüldü. Asistan vakalarınde en çok deneme 1 kez (1-3), başarılı giriş denemesi için geçen sure 7.25 dakika (2-12 dk.) ve skopi süresi ise 62.5 saniye (30-150 sn.) olarak saptandı.

Sonuç: Anatomik gösterge ve açıların bilinmesi, ürologların perkütan nefrolitotomide alt kaliks girişlerini daha başarılı şekilde yapmasını sağlayabilir.

Anahtar sözcükler: Anatomi; böbrek; böbrek taşı; girişim; perkütan nefrolitotomi.

[1]Department of Urology, Tepecik Education and Research Hospital, Izmir, Tukey

[2]Department of Urology, Ege University Faculty of Medicine, Izmir, Turkey

[3]Department of Anatomy, Ege University Faculty of Medicine, Izmir, Turkey

Submitted:
18.01.2012

Accepted:
20.03.2012

Correspondence:
Esat Kaan Akbay
Department of Urology, Tepecik Education and Research Hospital, 35110 Yenişehir, İzmir, Turkey
Phone: +90 232 343 62 63
E-mail: esatkaanakbay@yahoo.com

Available online at
www.turkishjournalofurology.com

Introduction

Percutaneous nephrolithotomy (PCNL) is an advanced endourologic procedure for the treatment of large and complex stone burdens in the renal pelvis and/or calices. The success of the initial puncture for percutaneous access during PCNL, guided by the fluoroscopic two-dimensional view of the collecting system, is absolutely critical for the outcome of the surgery.[1]

If appropriately performed, optimal efficacy with a low complication rate can be achieved. We conducted a prospective study to describe the external anatomical landmarks and angles for PCNL in the prone position under fluoroscopic guidance. With these anatomical landmarks and angles as a guide, we aim to decrease the learning curve of urology trainees for lower calyceal puncture during PCNL.

Materials and methods

Between 2006 and 2008, 50 patients scheduled for PCNL met the study criteria. The final 10 cases were resident cases. The inclusion criteria consisted of patients with renal stones scheduled for a lower calyceal puncture PCNL where the number of attempts to access the calyx ≤3, and clear urine was seen draining from the needle. The exclusion criteria consisted of previous ipsilateral kidney surgery, severe hydronephrosis, anomalies of the renal or skeletal systems, body mass index (BMI) >30 kg/m^2, a history of upper/middle calyceal punctures and patients ≤18 years of age.

The initial puncture in the first 40 cases was performed by one of the two experienced endourologists (BT and ON). Before the initial puncture, the following anatomical lines and points were marked by a sterile pen on the back of the patient during deep inspirium: the posterior axillary line (PAL), the posterior middle line (PML), the fluoroscopic vertical projection of the line traversing the upper edge of the iliac crest (UICL)], the tip of the twelfth rib (C point) and the fluoroscopic vertical projection of the lower edge of the lower calyx (Fig. 1). After marking these predetermined anatomical lines and points, the urologist used the fluoroscopic two-dimensional view of the collecting system, with the aid of retrograde contrast injected during inspirium, to assist with the skin puncture (N point) while aiming for the lower edge of the lower calyx (I point). When clear urine was seen draining from the needle, the guidewire is coiled within the collecting system. During needle removal, the length of the external portion of the needle outside of the patient (Pe) is measured. Next, the length of the needle within the patient (Pi) is calculated (Fig. 2-4). The tract is then dilated, a standard PCNL procedure is performed with the use of pneumatic lithotripsy, and a nephrostomy tube is placed in the tract at the end of the surgery.

At the completion of the procedure, several lengths were measured (a: the length between the N point and the PAL; b: the length between the N and C points; x: the length between the N point and the UICL; x1: the length between the transverse lines traversing the N and I points; y: the length between the I point and the PML; y1: the length between the sagittal lines traversing the N and I points; and t: the length between the N and I points). The results of these measurements were then used to calculate the 3 angles in the space relative to the marked skin entry and the lower edge of the lower calyx [α: the angle between t and x1; β: the angle between t and y1; γ: the angle between t and Pi (Cos γ=t/Pi) (the angle between the needle and the skin plane)].

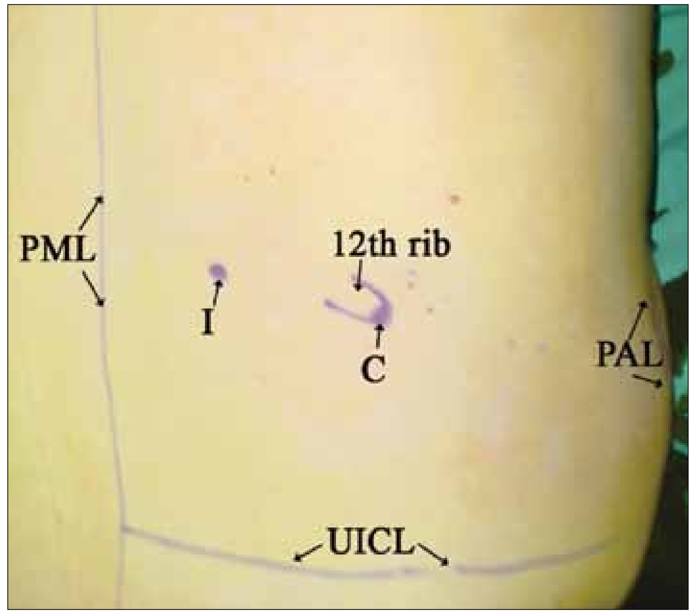

Figure 1. The Anatomical Landmarks before the Initial Puncture.
PML: Posterior Middle Line; PAL: Posterior Axillary Line; UICL: Upper Edge of the Iliac Crest Line; C: The Tip of the Twelfth Rib; I: Lower Edge of the Lower Calyx at Inspirium

Access was obtained in the final 10 patients by the two residents who were involved in the procedures from the beginning of the study and who ultimately developed an analytical description of what could be regarded as successful and safe access. In addition to the previous data, the fluoroscopy time, the number of attempts until successful access and the overall duration of the surgery until access were also recorded for each of these resident cases.

All data were prospectively collected. Descriptive statistics, Student's t-test and Pearson's correlation analysis were performed. Significance was defined as $p<0.05$.

Results

A total of 50 patients, with 34 male and 16 female patients (including 10 resident cases), were enrolled in the study. All percutaneous punctures were below the twelfth rib. The mean age, BMI, waist circumference and stone burden were 46.5±13.6 years (range 20-71), 26.1±3.2 (range 15-30), 95.1±11.1 cm (range 60-112) and 450.1±269.5 mm^2 (range 120-1750), respectively. Twenty-five operations were performed on the right kidney and 25 on the left kidney. All procedures, including the resident cases, were successfully completed without any intra-operative complications.

Turkish Journal of Urology 2012; 38(2): 74-79
doi:10.5152/tud.2012.018

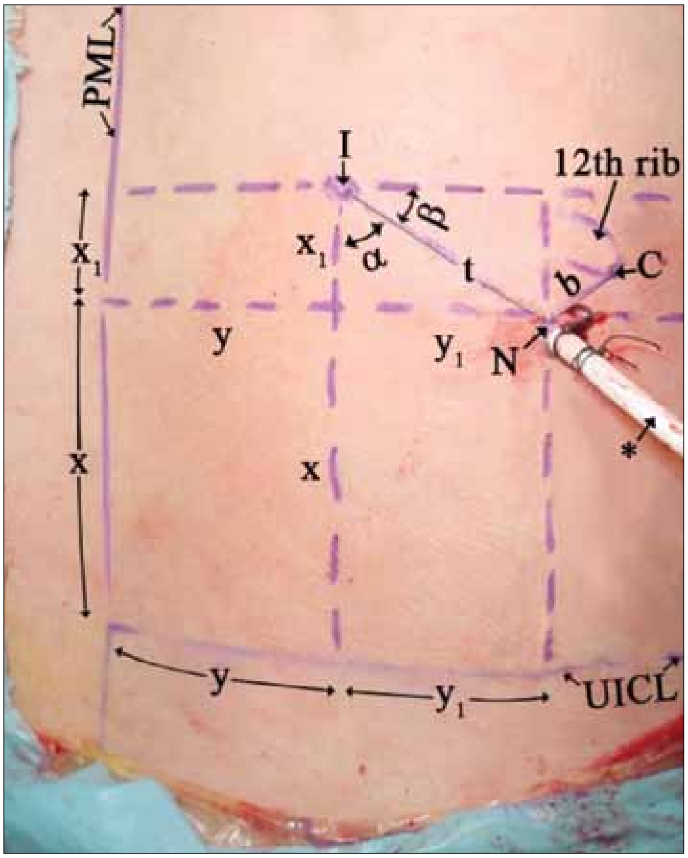

Figure 2. Measurement of the lengths and Angles at the Completion of the Procedure.
PML: The posterior middle line; UICL: The upper edge of the iliac crest line; I: The lower edge of the lower calyx at inspirium; N: The needle puncture point; C: The tip of the twelfth rib; x: The length between the N point and the UICL; x1: The length between the transverse lines traversing the N and I points; y: The length between the I point and PML; y1: The length between the sagittal lines traversing the N and I points; α: The angle between t and x1; β: The angle between t and y1; *: Nephrostomy tube

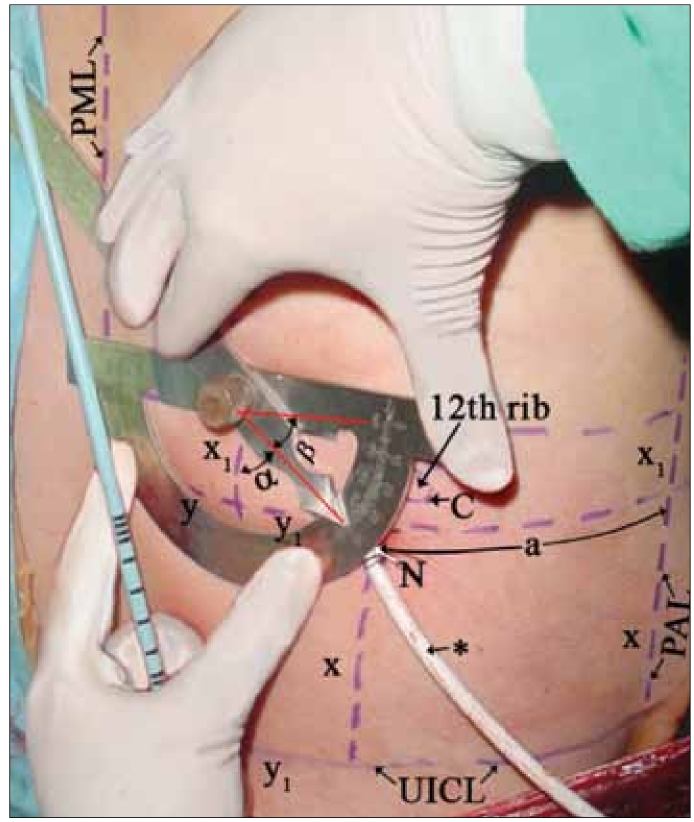

Figure 3. Measurement of the α and β angles.
*: Nephrostomy tube

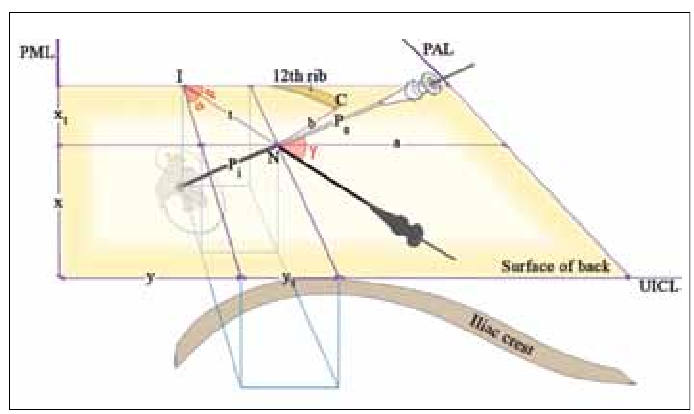

Figure 4. Schematic Presentation of the Anatomical Angles and lengths from the Posteroinferior View.

The mean length of (Pi) was 10.1±1.7 cm (range 7-14), (Pe) was 9.9±1.7 cm (range 6-13), (a) was 11.2±2.8 cm (range 5.5-17), (b) was 5.3±2.3 cm (range 1.5-11 cm), (x) was 5.1±1.9 cm (range 1-8), (x1) was 3.3±1.7 cm (range 1.5-8.2), (y) was 7.1±1.7 cm (range 3.3-11.6), (y1) was 3.8±1.6 cm (range 1-9) and (t) was 4.9±1.7 cm (range 3-9). The mean angle for (α) was 49±13º (range 30-70º), (β) was 41±13º (range 20-70º) and (γ) was 61±13º (range 28-80º). In the resident cases, the median number of attempts was 1 (range 1-3), the median overall time until successful access was 7.25 minutes (range 2-12) and the median fluoroscopy time was 62.5 seconds (range 30-150).

The mean values for most of the anatomical lengths and angles did not differ significantly between males and females. The only exception was the (y) length (p=0.004) (Table 1). There was also a trend towards a greater (γ) angle in the male population (p=0.062). When the right-sided procedures were compared with the left-sided procedures, the mean (x) length was significantly longer on the right side (p=0.004) (Table 2). However, the mean (γ) angle was significantly smaller on the right side (p=0.034). There was a positive correlation between the BMI and the (a) length (r=0.472, p=0.001) and the (α) angle (r=0.489, p=0.0001). However, there was a negative correlation between the BMI and the (Pe) length (r=-0.489, p=0.0001). There was no correlation found between age and any other parameter. Table 3 lists the parameters and their definitions.

Discussion

Minimally invasive surgical procedures have gained popularity and acceptance in recent years because they offer a shorter convalescence, improved cosmesis and a similar efficacy when compared with their more morbid open counterparts.[2] As experience has increased and the instruments have improved, PCNL has become the preferred approach for the removal of the majority of renal stones.[3]

Although percutaneous renal access is a basic step in percutaneous renal surgery, urologists rely on interventional radiologists to obtain renal access in many centers. Radiologists are said to have superior equipment and are skilled at obtaining renal access in less time.[4] However, in a study involving 1121 patients, El-Assmy et al demonstrated that urologists were able to safely and effectively obtain percutaneous renal access for PCNL in a single-stage procedure without the assistance of interventional radiologists.[5] In another study, Watterson et al.[6] retrospectively compared access-related complications between patients undergoing urologist-directed versus radiologist-directed renal access. Complications occurred less frequently and stone-free rates were higher in the urologist-directed access group.

In our institution, renal access is routinely performed by the urologist. We believe that the standard equipment used for PCNL is adequate for safe access. However, the learning curve for safe renal access is steep, and some surgeons may have concerns. Tanriverdi et al.[7] suggested that a novice surgeon could become competent after performing 60 cases of PCNL, and as surgical experience gradually increased, the operative and fluoroscopy screening times were significantly reduced.

Table 1. The mean values of the anatomical landmarks in relation to sex

	Male (n=34)	Female (n=16)	P value
Pi (cm)	10±1.6 (7-13)	8±2.1 (7-14)	0.769
Pe (cm)	10±1.6 (7-13)	9.8±2.1 (6-13)	0.769
a (cm)	11.2±2.9 (5.5-17)	11±2.8 (7.3-16.)	0.841
b (cm)	5.3±2.1 (2-11)	5.7±2.8 (1.5-11)	0.545
x (cm)	4.9±2.1 (1-8)	5.4±1.6 (2-8)	0.419
x1 (cm)	3.5±1.7 (1.5-8.2)	2.9±1.7 (1.5–8.1)	0.307
x + x1 (cm)	8.4±2.4 (3.1-15.4)	8.3±1.4 (6.3-10.3)	0.921
y (cm)	7.5±1.7 (4.2-11.6)	6.1±1.5 (3.3-8.5)	0.004
y1 (cm)	3.6±1.6 (1.00-9.00)	4.2±1.7 (2.5-7.3)	0.217
y + y1 (cm)	11.1±2.2 (7.5-19)	10.3±2 (7.3-13)	0.194
t (cm)	4.9±1.7 (3.2-9)	4.8±1.7 (3-9)	0.836
α (°)	46.7±12.4 (30-70)	53.3±13.8 (30-70)	0.097
β (°)	43.3±12.4 (20-60)	37.3±15.2 (20-70)	0.145
γ (°)	63.2±10.6 (34-80)	55.9±15.8 (27.5-77.5)	0.062

Table 2. The mean values of the anatomical landmarks in relation to the operative side

	Right (n=25)	Left (n=25)	P value
Pi (cm)	10±1.8 (7-13)	10.1±1.7 (7.7-14)	0.648
Pe (cm)	10±1.8 (7-13)	9.9±1.7 (6-12.3)	0.648
a (cm)	11±2.5 (6-17)	11.5±3.2 (5.5-16)	0.289
b (cm)	5±2.4 (1.5-11)	5.8±2.2 (2-11)	0.144
x (cm)	5.8±2 (1-8)	4.3±1.6 (1-7.2)	0.004
x1 (cm)	3±1.2 (1.5-6.5)	3.7±2.1 (1.5-8.2)	0.141
x + x1 (cm)	8.8±1.4 (6.5-10.7)	7.9±2.6 (3.1-15.4)	0.177
y (cm)	7±1.5 (4.2-10)	7.1±1.9 (3.3-11.6)	0.939
y1 (cm)	4.1±1.9 (1-9)	3.5±1.2 (2.1-7.2)	0.218
y + y1 (cm)	11.1±2.4 (7.3-19)	10.6±1.9 (7.7-14.6)	0.386
t (cm)	5.1±1.9 (3-9)	4.6±1.3 (3.5-8)	0.299
α (°)	48.9±14.6 (30-70)	48.8±11.7 (30-70)	0.953
β (°)	41.5±15.3 (20-70)	41.2±11.7 (20-60)	0.890
γ (°)	58.2±14.1 (27.5-77.5)	63.5±11 (27.5-80)	0.034

Turkish Journal of Urology 2012; 38(2): 74-79
doi:10.5152/tud.2012.018

Table 3. The abbreviations of terms and landmarks in alphabetical order

Abbreviation on figure	Explanation
*	Nephrostomy tube
α	The angle between t and x1
β	The angle between t and y1
a	The length between the N point and the PAL
b	The length between the N and C points
C	The tip of the twelfth rib
I	The lower edge of the lower calyx at inspirium
N	The needle puncture point
PAL	The posterior axillary line
Pe	The external portion of the needle outside the patient
Pi	The internal portion of the needle inside the patient
PML	The posterior middle line
t	The length between the N and I points
UICL	The upper edge of the iliac crest line
x	The length between N point and UICL
x1	The length between the transverse lines traversing the N and I points
y	The length between the I point and PML
y1	The length between the sagittal lines traversing the N and I points

Unlike other surgical procedures, percutaneous access is performed only once per procedure, which means that only a limited amount of experience is gained per procedure. Despite this, few models have been developed to train urologists in percutaneous renal access. In our review of the literature, we found only two instances of high-fidelity bench models and one detailed description of the use of a virtual-reality simulator used to train urologists in percutaneous renal access.[8-10] Hammond et al.[8] filled cadaver porcine kidney collecting systems with pebbles to simulate stones and placed each renal/ureteral unit inside a chicken carcass.Using fluoroscopic guidance, trainees performed percutaneous renal puncture and the various other steps of the procedure. The authors noted that the residents who participated in this model of training expressed a higher level of confidence with the equipment for and the technique of renal access. Strohmaier and Giese developed an ex-vivo animal model for the training of physicians in percutaneous renal access that utilized cadaveric porcine kidneys and ureters into which calculi of different sizes and compositions were placed.[9] With the use of ultrasound guidance, a percutaneous needle puncture was performed and guidewire passage was verified using fluoroscopy and by opacifying the collecting system with a retrograde-injected contrast medium. The PERC Mentor™ (Simbionix, Lod, Israel) is a virtual reality simulator developed specifically for training physicians in percutaneous renal puncture. Knudsen et al.[10] evaluated the utility of the PERC Mentor and demonstrated that virtual reality training improved the skill of novice surgeons in performing percutaneous renal access.To perform accurate renal access, Cadeddu et al.[11] developed a device called the PAKY (Percutaneous Access to the KidneY), a mechanical stereotactic frame and actuated needle system that could be used as a platform for needle placement. However, the PAKY is not routinely used in clinical practice at this time.

Despite the introduction of such models, hands-on training in the operating room has remained the essential method for learning percutaneous renal access. We strongly believe that urologists should be encouraged to learn how to safely perform percutaneous punctures themselves. Therefore, we conducted this prospective study to describe the external anatomical landmarks and angles to train urologists to perform safe percutaneous renal access in the prone position under fluoroscopic guidance.

The results of our study showed that several anatomical landmarks and angles provide an anatomical basis for safe and efficient renal access for lower calyceal punctures. We noted that both the lengths and the angles are important measurements for achieving exact renal access. Because the sum of the angle (α) and (β) is always 90°, urologists should avoid high values for (α) or (β). Similarly, the γ angle (the angle between the needle and the skin plane) should not have an excessively high value. We used the following formula to calculate the (γ) angle to avoid any mistakes in measurements: $\cos \gamma = t/Pi$. The (γ) angle is particularly useful for estimating the insertion angle between the needle and the skin. A correct assessment of the measurements, especially the lengths of (x1), (y1), (t) and (Pi), is an important consideration for proper orientation in renal access.

In our study, the lengths and angles measured did not show a wide variation in most patients. The mean values for most anatomical lengths and angles did not differ significantly between males and females, except for the (y) length. There was also a trend towards a greater (γ) angle in the male population. In the right-sided procedures, the mean (x) length was significantly longer and the mean (γ) angle was significantly shorter. These measurements may be due to the anatomical differences in patients or due to the small number of patients. The length of the (a) and (α) angle showed a positive correlation to the BMI. However, the (Pe) length showed a negative correlation to the BMI. These results are not surprising because of the shorter (Pe) and longer (a) lengths in overweight patients.

Initially, it may be difficult to understand and appreciate the use of the lengths and angles we describe for use during PCNL, but once the principles are understood, we believe that these mathematical results can serve as a guide for the successful performance of renal access. One limitation of our study is that these anatomical landmarks were defined using our standard patients, which excluded obese patients, young patients and patients with a previous history of surgery, renal anomaly and hydronephrotic kidneys. An additional limitation of our study is that there was no control group. Despite the limitations, to our knowledge, this is the first study of its kind that attempted to determine anatomical landmarks for PCNL. The study takes its power from its prospective design.

In resident cases, we calculated the mean number of attempts, the mean overall time until successful access and the mean fluoroscopy time to observe how the anatomical landmarks can assist novice surgeons achieve successful renal access. The mean number of attempts was 1.7, the mean overall time until successful access was 7 minutes and the mean fluoroscopy time was 70 seconds. All of the procedures, including the resident cases, were successfully completed without any intra-operative complications. The anatomical landmarks and angles significantly assisted with the teaching of safe renal access to urologists. Further training and validation are needed for these measurements to be routinely used in clinical practice.

Conclusion

A knowledge of these anatomical landmarks and angles may increase the capacity of urologists to repetitively perform the precise task of percutaneous access of the lower calyceal during PCNL. However, the validation of our data among different patient populations with a greater number of patients is required to recommend the use of these data in urology training programs.

Conflict of interest
No conflict of interest was declared by the authors.

References

1. Marcovich R, Smith A. Percutaneous renal access: tips and tricks. BJU Int Supplement 2 2005;95:78-84.
2. Bauer J, Lee BR, Stoianovici D, Bishoff JT, Micali S, Micali F, et al. Remote percutaneous renal access using a new automated telesurgical robotic system. Telemedicine Journal and e-heath 2001;7:341-6.
3. Wong MY. An update on percutaneous nephrolithotomy in the management of urinary caluli. Curr Opin Urol 2001;11:367-72. [CrossRef]
4. Lee CL, Anderson JK, Monga M. Residency training in percutaneous renal Access:does it affect urological practice? J Urol 2004;171:592. [CrossRef]
5. El-Assmy AM, Shokeir AA, Mohsen T, El-Tabey N, El-Nahas AR, Shoma AM, et al. Renal access by urologist or radiologist for PNL-is still an issue? Journal of Urol 2007;178:916-20. [CrossRef]
6. Watterson JD, Soon S, Jana K. Access related complications during PNL: Urology versus radiology at a single academic institution. J Urol 2006;176:142-5. [CrossRef]
7. Tanrıverdi O, Boylu U, Kendirci M, Kadıhasanoğlu M, Horasanlı K, Miroglu C. The learning curve in the training of percutaneous nephrolitotomy. Eur Urology 2007;52:206-12. [CrossRef]
8. Hammond L, Ketchum J, Schwartz BF. A new approach to urology training: a laboratory model for percutaneous nephrolitotomy. J Urol 2004;172:1950-2. [CrossRef]
9. Strohmaier WL, Giese A. Ex vivo training model for percutaneous renal surgery. Urol Res 2005;33:191-3. [CrossRef]
10. Knudsen BE, Matsumoto ED, Chew BH, Johnson B, Margulis V, Cadeddu JA, et al. A randomized, controlled, prospective study validating the acquisition of percutaneous renal collecting system access skills using a computer based hybrid virtual reality surgical Simulator: Phase I. J Urol 2006;176:2173-8. [CrossRef]
11. Cadeddu JA, Stoianovici D, Chen RN, Moore RG, Kavoissi LR. Stereotactic mechanical percutaneous renal access. J of Endourol 1998;12:121-5. [CrossRef]