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A hypothetical method for calculation of the access point, direction angle and access angle for percutaneous nephrolithotomy

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ABSTRACT

Urinary stone disease has an increasing prevalence across the globe, and endoscopic treatment modalities have replaced open surgery. Percutaneous nephrolithotomy (PCNL) is a successful, safe and reliable minimally invasive method in the treatment of renal stones, especially big (≥2 cm) or complex ones. Gaining access is the most critical step of this procedure, which can affect the rest of the operation. Although previously described techniques, eye of the needle and triangulation techniques, are being used for gaining access, urologists (especially novice ones) can still have problems during this step. Some navigation concepts have been developed in order to make the access safer, easier and more successful, however, none of them has been incorporated in daily routine practice till now because of either complicated techniques or requirement of sophisticated equipment. Our hypothesis is that the access point, direction angle and access angle in order to touch a stone during PCNL can be calculated by the data obtained from the computed tomography images with the help of mathematical formulations, namely the theorem of the cosine.

Introduction

Urinary system stone disease is a growing public health problem, which is a chronic pathophysiological process characterized by deposit of minerals generally as calcium oxalate and calcium phosphate. Stone disease affects 5–10% of the world population. Its prevalence in the USA is 10.1–12% in men and 6–8% in women [1]. The prevalence has doubled in the last 15 years [1]; therefore numerous patients admit to hospitals every year for treatment. Direct medical cost for stone disease has been reported to be 10 billion USD in 2012 for the USA [2]. This number is expected to increase 1.24 billion USD per year in year 2030 due to increase in prevalence of obesity and diabetes, and increase in population [3]. Stone disease treatment is planned according to the age and weight of patient, and the localization, dimension and kind of stone. Treatment options for kidney stones consist of extracorporeal shock wave lithotripsy (ESWL), and endoscopic (percutaneous nephrolithotomy [PCNL], semi-rigid ureterorenoscopy [URS], retrograde intrarenal surgery [RIRS]), laparoscopic or open surgery. The importance and usage of minimally invasive treatment modalities have recently increased. In a study performed in 2009–2010 in the UK, it was found that open surgery has decreased 83% while PCNL and URS have increased 127%, and these two interventions have been performed more than the sum of nephrectomies, radical prostatectomies and radical cystectomies [4].

The basis of PCNL goes back to removal of a kidney stone by creating a nephrostomy tract during an operation by Rupel and Brown in 1941 [5]. Although Goodwin et al. have stated that percutaneous nephrostomy could be used for the treatment of obstruction and infection in 1955, creation of a percutaneous tract during a successful endoscopic treatment of a kidney stone has been executed by Fernström and Johansson in 1976 [6,7]. This minimally invasive treatment, which is recommended for stones those are larger than 2 cm, multiple, in complex structure (coraliform) or resistant to ESWL by both European Association of Urology (EAU) and American Urology Association (AUA), has a shorter hospitalization and convalescence time, less postoperative pain, and better cosmetic outcomes [8–10]. The success rate of this treatment modality is generally reported to be around 90% and even near 100% in experienced tertiary centers [11]. The complications consist of hemorrhage (1–3%), blood transfusion (2–23%), pulmonary injury (8–50% during intercostal access), perforation of

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renal pelvis or bowels (0.6–1%) and liver/spleen injury [11,12].

The first step of the PCNL, which is also the most important and the most difficult to learn, is the determination of the most appropriate access point and creation of a tract into the desired calyx. In order to minimize complication risk, renal and perirenal anatomy should be well known. Entry to the collecting system can be performed with the aid of either fluoroscopy or ultrasound, both having their own advantages and disadvantages. Various navigation concepts and computer-assisted systems have been developed in order to make the access safer, easier and more successful, and to minimize radiation dose; however, none of them has been incorporated in daily routine practice.

Hypothesis

Our hypothesis is that the access point, direction angle and access angle in order to enter the desired point of the collecting system (where the stone resides) can be calculated by the data gained from the computed tomography (CT) scan of a patient with the help of some mathematical formulations. We first create a good geometrical description of the stone position, and then apply some basic formulations (such as the theorem of the cosine) to estimate the most appropriate access point on the skin surface and to measure the access angle and the direction angle.

Methods

In our hypothesis, this measurement can be performed by asking the surgeon at which point he/she wants to touch the stone or to puncture the collecting system (point *S*).

The steps of calculation according to this assumption:

1. PCNL is generally performed with a direction angle of 45 ± 2°, and from our experience, we can say that this angle ranges between 40° and 50°. By using the theorem of the cosine, it can be shown that only a few millimeters vary when a direction angle is assumed 43° or 47° (less than 5 mm). Therefore, the direction angle will first be assumed as 45° here.
2. The surgeon identifies an estimated access point (point *M*) on a CT section, which shows the desired point to touch the stone or to puncture the collecting system (point *S*) (Fig. 1-a). In this figure, point *S* represents the stone, point *P* represents the projection point of the stone on the skin surface at 90°, point *M* represents the estimated access point that the surgeon identifies. Line *a* stands for the distance between the stone (point *S*) and the projection point (on y axis) (point *P*), line *b* represents the distance between the stone (point *S*) and the estimated access point (point *M*), and line *c* stands for the distance between the projection point (point *P*) and the estimated access point (point *M*).
3. In order to make the access from the correct point, point *M* is turned according to the direction angle (β); therefore, line *b* and line *c* become line *d* and line *e*, respectively (Figs. 1-b and 2). Point *N* is the new position of point *M*. Line *d* represents the distance between the stone (*S*) and point *N*, where line *e* stands for the distance between the projection point (*P*) and point *N*.
4. When line *c* is repositioned as line *e*, while turning according to the direction angle (β), point *M* goes up because of the arc. This shift has to be corrected and point *M* has to be repositioned as point *R* (real access point), which is on the same plane with point *M* (Figs. 2–4). As line *c* and line *i* are perpendicular to each other, the new distance (line *h*) created with the extension of line *e* will be a hypotenuse, which can be calculated with the below formula:

$$h = \frac{e}{\cos ß}$$

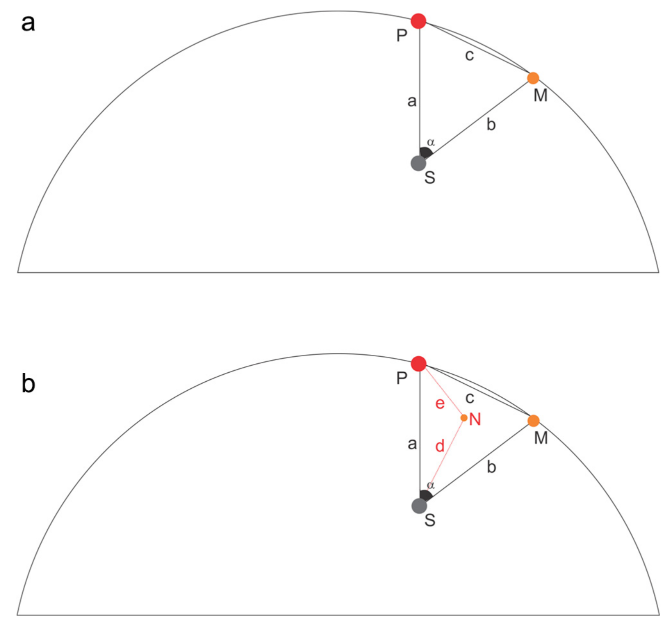

Fig. 1. a) and b) Coronal CT scan slice at the level of the point where the access is targeted to (either to touch a stone or to enter interior of collecting system).

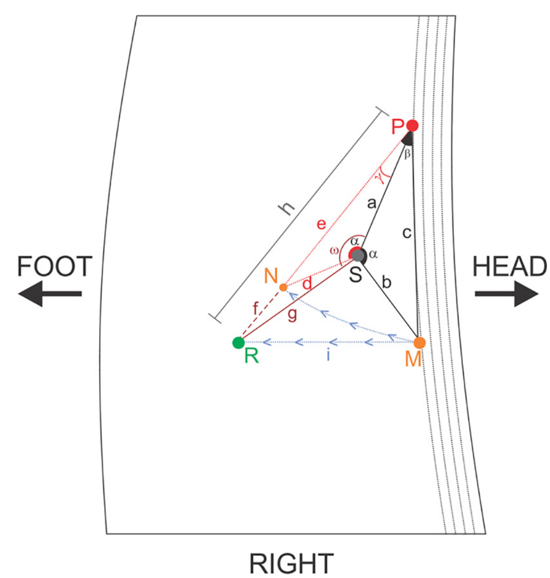

Fig. 2. Schematic explanation of the target point (where the stone lies), projection point (of the stone), and geometry to identify the access point at bird's eye view.

5. As line *e* is extended (line *f*) to take point *N* to point *R*, the access angle (α) widens and becomes ω, the real access angle (Figs. 2–4). In order to calculate ω, the angle γ has to be known which can be calculated with the following formula:

$$\cos\gamma = \frac{d^2 - (a^2 + e^2)}{-2ae}$$

6. After calculation of cos γ, the distance (line *g*) between the real access point (*R*) and the stone (*S*) can be calculated with the help of the theorem of the cosine.

$$g = \sqrt{a^2 + h^2 - 2ah\cos\gamma}$$

7. The real access angle ω can now be calculated by using the theorem of the cosine again:

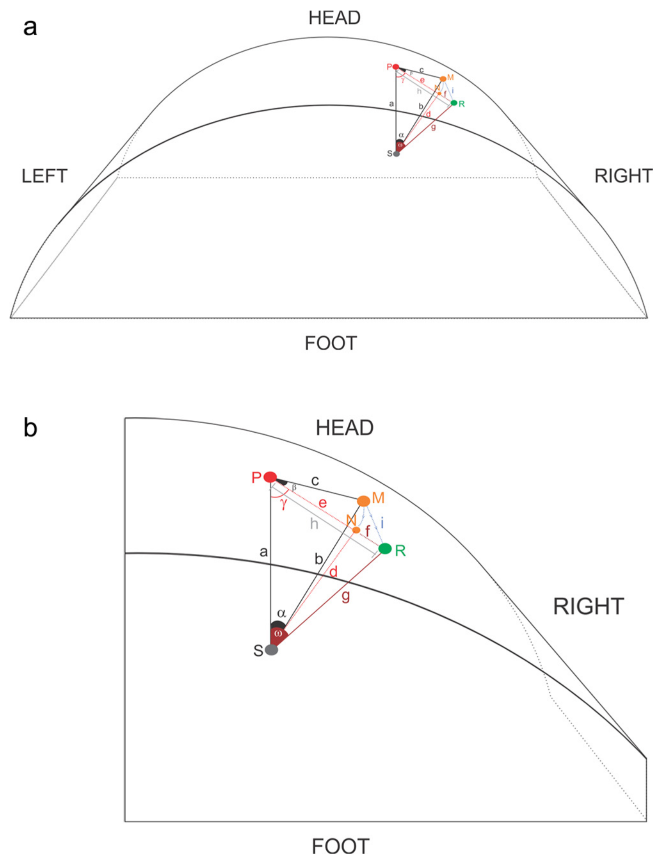

Fig. 3. a) Schematic explanation of the target point, projection point, and geometry to identify the access point, direction angle and access angle at rear oblique view. b) Magnified view of the region of interest.

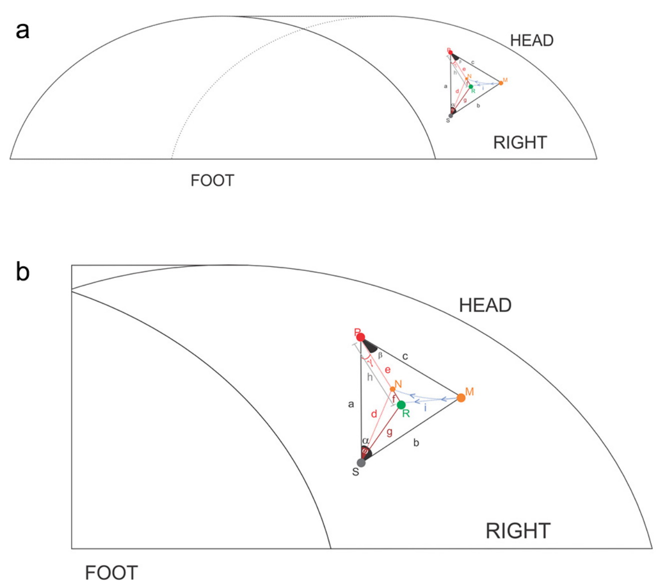

Fig. 4. a) Schematic explanation of the target point, projection point, and geometry to identify the access point, direction angle and access angle at right lateral oblique view. b) Magnified view of the region of interest.

$$\cos\omega = \frac{h^2 - (a^2 + g^2)}{-2ag}$$

Descriptions

Point S: Stone or interior of collecting system (target point)
Point P: Projection point of stone
Point M: Estimated access point that the surgeon identifies
Point N: New (transposed) position of point M
Point R: Real access point
a: The distance between the stone (S) and the projection point (P)
b: The distance between the stone (S) and the estimated access point (M)
c: The distance between the projection point (P) and the estimated access point (M)
d: The “new” line b (when point M is transposed to point N)
e: The “new” line c (when point M is transposed to point N)
f: The distance between the transposed point M (N) and the real access point (R)
g: The distance between the real access point (R) and the stone (S)
h: The distance between the real access point (R) and the projection of stone (P)
i: The distance between the real access point (R) and the estimated access point (M)
α: Estimated access angle (∠PSM)
β: Direction angle (∠RPM)
γ: Calculated angle that helps to identify real access angle (∠NPS)
ω: Real access angle (∠RSP)

Discussion and conclusion

Making the right access is the most critical step of PCNL, as the remaining of the procedure can be performed easily and expeditiously if the access is done correctly, whereas this surgery can be troublesome and grueling with increased risk of complications if the initial access is gained poorly. Till now, two different access techniques have been identified in order to puncture the collecting system by using fluoroscopy during PCNL: ‘eye of the needle’ and ‘triangulation’ techniques [13]. Various papers have showed the feasibility of both techniques in either sequential or one-stage dilatation of the PCNL access. Research has also shown that an access obtained by a urologist had less access-related complications and better stone-free rates with similar access difficulties when compared to the one gained by an interventional radiologist [14]. However, Lee et al. reported that only 27% of urologists who have trained on percutaneous access during their residency continued to perform their own access for PCNL [15]. Therefore, with taking these data into consideration, one can say that it would be better if an easy-to-understand-and-to-perform technique can be described in order to encourage urologists to perform a successful and safe access on their own.

We think that the hypothesis described here can be a solution for the problems encountered during gaining access, as these calculations are not complicated formulations, and required data can be easily gathered from preoperative CT images. These calculations do not require the surgeon to have advanced mathematical skills. Moreover, an application or web-based software can be developed in order to make the process convenient and work faster. A non-contrast CT (if the aim is to touch a stone) or a late phase contrast-enhanced CT (CT-urography) (if interior of collecting system is targeted) taken in prone position (where two gel cushions are placed under the chest of a patient – that is the same position in PCNL) is enough to make the proposed calculations. In addition to its use in endoscopic stone surgery, this technique can also be used in calculation of the access point during percutaneous thermal/cryo-ablation of small renal masses, which is becoming more popular and frequently used nowadays, especially for the patients who are not eligible/willing for partial/radical nephrectomy.

Although this hypothesis can be tested on a gel cushion or a chicken model, which have been used previously [16], it would be better to test this hypothesis on a human-like phantom (such as a plaster mold taken from a volunteer which is filled with ballistic gel or a commercially available PCNL training model [i.e., PCNL Training Device LS40 – Samed GmbH, Dresden, Germany]), as a spatial error may occur because of the complex surface anatomy of the lumbar region and body habitus in humans. However, even with such a model, not all of the variables (i.e., slight movement of kidney/stone during respiration, deformation on skin while needle is introduced, or deformation of needle, etc.) that could be encountered during a real PCNL operation can be taken into account.

In conclusion, we argue that this hypothesis can be useful for urologists, especially who have less experience in PCNL or the novice ones, in gaining percutaneous access on their own with high success rates and minimal complication rates.

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.mehy.2019.02.007.

References

[1] Scales Jr CD, Smith AC, Hanley JM, Saigal CS. Urological Diseases in America Project. Prevalence of kidney stones in the United States. Eur Urol 2012;62:160–5.
[2] Litwin MS, Saigal CS. National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Health, Public Health Service, US Department of Health and Human Services. Table 14-47: Economic impact of urologic disease 12-7865 Urologic Diseases in AmericaWashington, DC: NIH Publication; 2012. p. 486.
[3] Antonelli JA, Maalouf NM, Pearle MS, Lotan Y. Use of the National Health and Nutrition Examination Survey to calculate the impact of obesity and diabetes on cost and prevalence of urolithiasis in 2030. Eur Urol 2014;66:724–9.
[4] Turney BW, Reynard JM, Noble JG, Keoghane SR. Trends in urological stone disease. BJU Int 2012;109:1082–7.
[5] Rupel E, Brown R. Nephroscopy with removal of stone following nephrostomy for obstructive calculous anuria. J Urol 1941;46:177.
[6] Goodwin WE, Casey WC, Woolf W. Percutaneous trocar (needle) nephrostomy in hydronephrosis. J Am Med Assoc 1955;157:891–4.
[7] Fernstrom I, Johansson B. Percutaneous nephrolithotomy: a new extraction technique. Scand J Urol Nephrol 1976;10:257–9.
[8] Türk C, Petrik A, Sarica K, et al. EAU Guidelines on interventional treatment for urolithiasis. Eur Urol 2016;69:475–82.
[9] Assimos D, Krambeck A, Miller NL, et al. Surgical management of stones: American Urological Association/Endourological Society Guideline. Part I. J Urol 2016;196:1153–60.
[10] Assimos D, Krambeck A, Miller NL, et al. Surgical management of stones: American Urological Association/Endourological Society Guideline. Part II. J Urol 2016;196:1161–9.
[11] Kamphuis GM, Baard J, Westendarp M, de la Rosette JJ. Lessons learned from the CROES percutaneous nephrolithotomy global study. World J Urol 2015;33:223–33.
[12] Michel MS, Trojan L, Rassweiler JJ. Complications in percutaneous nephrolithotomy. Eur Urol 2007;51:899–906.
[13] Miller NL, Matlaga BR, Lingeman JE. Techniques for fluoroscopic percutaneous renal access. J Urol 2007;178:15–23.
[14] Watterson JD, Soon S, Jana K. Access related complications during percutaneous nephrolithotomy: urology versus radiology at s single academic institution. J Urol 2006;176:142–5.
[15] Lee CL, Anderson JK, Monga M. Residency training in percutaneous renal access: does it affect urological practice? J Urol 2004;171:592–5.
[16] Hacker A, Wendt-Nordahl G, Honeck P, Michel MS, Alken P, Knoll T. A biological model to teach percutaneous nephrolithotomy technique with ultrasound- or fluoroscopy-guided access. J Endourol 2007;21:545–50.