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Proposal for a cadaveric training model for percutaneous renal access

Propuesta de un modelo cadavérico de adiestramiento para acceso renal percutáneo

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Abstract

OBJECTIVE: To describe a cadaveric training model for percutaneous renal access.

MATERIALS AND METHODS: Descriptive study of a cadaveric model of training for fluoroscopy-guided percutaneous renal access. Punctures were performed using the triangulation technique in the supine position. Four urology residents were evaluated comparing initial punctures guided by an expert and subsequently trial punctures performed without the expert. The success rate, the number of attempts per puncture, and the radiation time were evaluated.

RESULTS: Ten kidneys from 6 cadaveric models were used. The total number of punctures was 119, with 73 (61.4%) initial punctures and 46 (38.6%) trial punctures, with a mean of 12 ± 9.92 punctures per kidney. The overall puncture success rate was 50.4% (60/119), the mean radiation time was 1.3 ± 0.8 min. The initial puncture success was 41% (30/73) and 65.2% (30/46) in the trial punctures ($p < 0.01$). Fluoroscopy time was 1.49 ± 0.95 min v. 1.07 ± 0.52 min ($p < 0.01$), respectively, being significantly longer in the initial punctures.

CONCLUSIONS: The proposed cadaveric training model is a useful and reproducible tool for renal access in percutaneous procedures for urology trainees. Exposure to radiation among practitioners is a disadvantage that must be considered.

KEYWORDS: Percutaneous renal access; Cadaveric; Fluoroscopy; Supine position; Punctures; Kidney; Urology.

Resumen

OBJETIVO: Describir un modelo de adiestramiento cadavérico para acceso renal percutáneo.

MATERIALES Y MÉTODOS: Estudio descriptivo de un modelo cadavérico de adiestramiento para acceso renal percutáneo guiado por fluoroscopia. Las punciones se realizaron mediante la técnica de triangulación en posición decúbito supino. Se evaluó la participación de residentes de Urología *vs* punciones iniciales asesorados por un experto, y punciones de prueba ejecutadas sin asesores. Se estimó el porcentaje de éxito, la cantidad de intentos por punción y el tiempo de radiación.

RESULTADOS: Se utilizaron 10 riñones de 6 modelos cadavéricos. En total se efectuaron 119 punciones: 73 (61.4%) iniciales y 46 (38.6%) de prueba, con una media de 12 ± 9.92 punciones por riñón. La tasa de éxito por punción fue del 50.4% y (60 de 119) el tiempo medio de radiación de 1.3 ± 0.8 min. El éxito de punciones iniciales fue del 41% (30 de 73) y de prueba del 65.2% (30 de 46; $p < 0.01$). El tiempo de fluoroscopia fue de 1.49 ± 0.95 min y 1.07 ± 0.52 min ($p < 0.01$), respectivamente, con significación estadística en los primeros.

CONCLUSIONES: El modelo de adiestramiento propuesto es una técnica útil y reproducible para el acceso renal en procedimientos percutáneos para el urólogo en formación. La exposición a la radiación entre practicantes es una desventaja que debe considerarse en la práctica clínica de la Urología.

PALABRAS CLAVE: Acceso renal percutáneo; cadáver; fluoroscopia; posición supina; punciones; riñón; Urología.

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INTRODUCTION

The first percutaneous nephrolithotomy (PCNL) described in literature was in 1976, performed with the patient in the prone position, with the intention of replacing open surgery, which had previously been the choice for large kidney stones.[1] Currently, PCNL is considered the treatment of choice for stones >2 cm and complex stones found in the calyces, renal pelvis, or ureteropelvic junction.[2] Later, in 1988, Valdivia et al described the technique in the supine position.[3]

One of the most complex steps in PCNL is the percutaneous puncture to access the renal collecting system. There are multiple techniques described for percutaneous renal access. The correct anatomical identification of the collecting system has been considered the key to a correct approach, and fluoroscopy, the most commonly used imaging technique for puncture guidance.[4] The learning curve for PCNL remains challenging. Obtaining an appropriate percutaneous access to the renal cavities reduces the risk of complications, such as bleeding and injury to neighboring organs. In addition, a higher stone-free rate has been demonstrated.

Currently, there are multiple training models for urologists in training in different procedures, such as laparoscopic and endourological, but few in relation to percutaneous renal access. Some described learning methods include non-biological, biological, and virtual reality inanimate simulators.[5-9]

The objective of this study is to describe our proposal for a cadaveric training model for percutaneous renal access.

MATERIALS AND METHODS

An experimental and analytical prospective study was carried out in the clinical anatomy and surgical training laboratory (LACEQ in Spanish) of the Faculty of Medicine of the Autonomous University of Nuevo León (UANL in Spanish) from November 2020 to June 2021. Approval of institutional ethics and research committees were granted. Six bodies were included for the preparation of the training model. The bodies were previously embalmed with a carbowax technique and kept at a temperature of 2 degrees Celsius. A Chiba 18 Gauge/20 cm needle was used for puncture. The punctures were guided by radiographic images, for which a mobile C-arm fluoroscope was used. Radiation protection equipment was used, including a lead vest, thyroid protector, and lead glasses. The "as low as reasonably achievable" (ALARA) safety principle was followed for radiation exposure.

Preparation of the training model

Preparation begins with a midline suprapubic incision extending into both inguinal folds. The abdominal wall is dissected down to the bladder. A wide vertical midline cystostomy is performed and both ureteral meatuses are subsequently identified. They are cannulated with a hydrophilic guidewire and an open-end ureteral catheter (**Figure 1**). Once the ascent of the guide wire towards the ureter has been corroborated, a retrograde pyelography with iodinated contrast is performed in order to confirm the correct canalization of the collecting system by fluoroscopic image (**Figure 2**). The topography of the eleventh and twelfth ribs, the iliac crest and the posterior axillary lines are marked, which allows the safety zone for puncture to be identified. **Figure 3**

Puncture Technique

The cadaver is positioned at a 20-degree angle with respect to the surgical table. The percutaneous puncture is performed in the supine position guided by fluoroscopy. The needle is inserted over the puncture site previously identified as the safety zone. A renal papilla is selected for access and the needle is inserted using the triangulation

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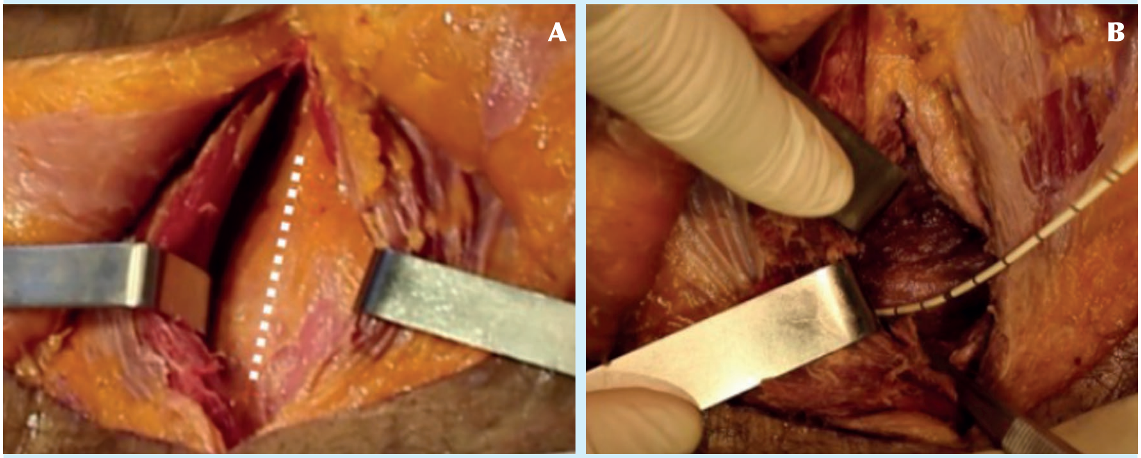

Figure 1. A) Bladder opening through vertical midline incision; **B)** cannulation of the ureter through a hydrophilic guidewire and subsequent introduction of an open-end ureteral catheter.

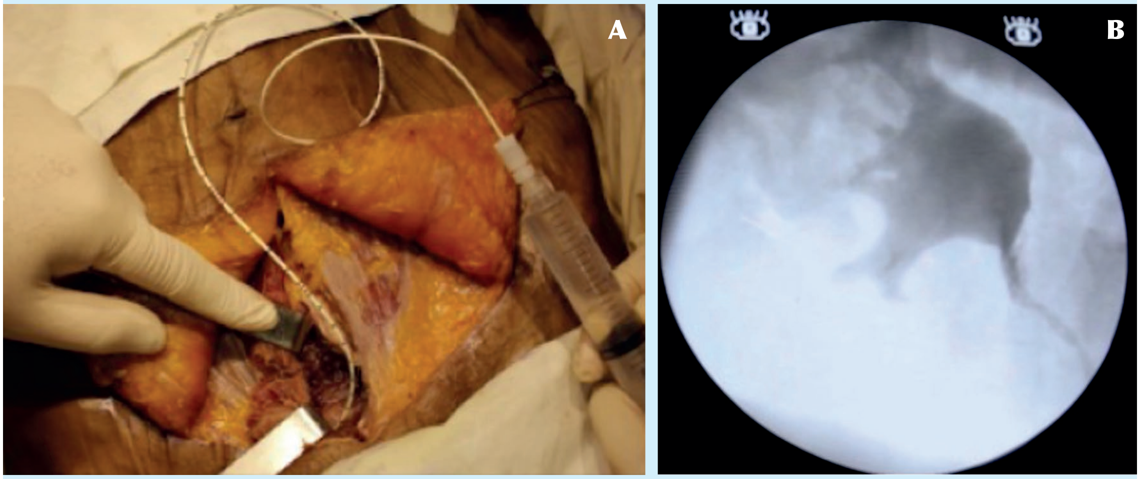

Figure 2. A) Water-soluble iodinated contrast is diluted to 50% with normal saline solution and placed in a 20cc syringe. It is attached to the end of the open-end catheter and slowly infiltrated. **B)** The C-arm is positioned on the renal silhouette and images of the collecting system are obtained by fluoroscopy.

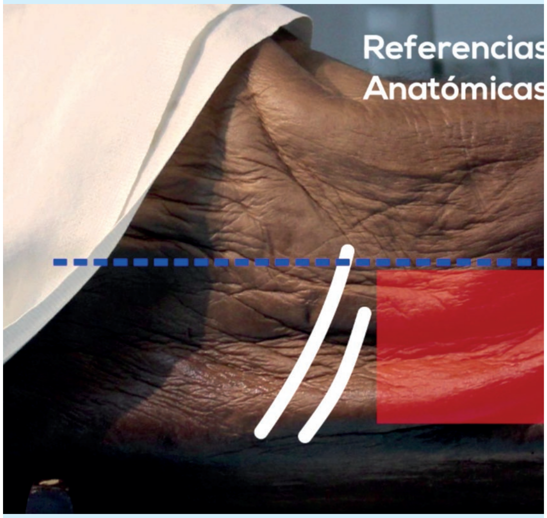

Figure 3. Anatomical references for the identification of the safety zone for puncture (red zone). The ends of the eleventh and twelfth ribs (parallel soft lines) are identified. The upper border of the iliac crest is marked (single white line). A line is drawn at the level of the posterior axillary line (intermittent blue line).

technique (**Figure 4**). Once the renal papilla is reached, access to the collecting system is confirmed by the return of fluid through the needle.

Evaluation of the model

Four urology residents performed the punctures. The time required for the preparation of the model, the success to cannulate the ureters, the number of punctures in each kidney and the number of punctures per renal calyx were evaluated. The number of punctures in each kidney was established based on the quality and clarity of the fluoroscopic image of the collecting system, since for each puncture performed there is distortion of the collecting system due to leakage of contrast material.

A comparison was made between the initial punctures in the model, which were guided by an expert in the field (>100 procedures), and later trial punctures without an expert by the same

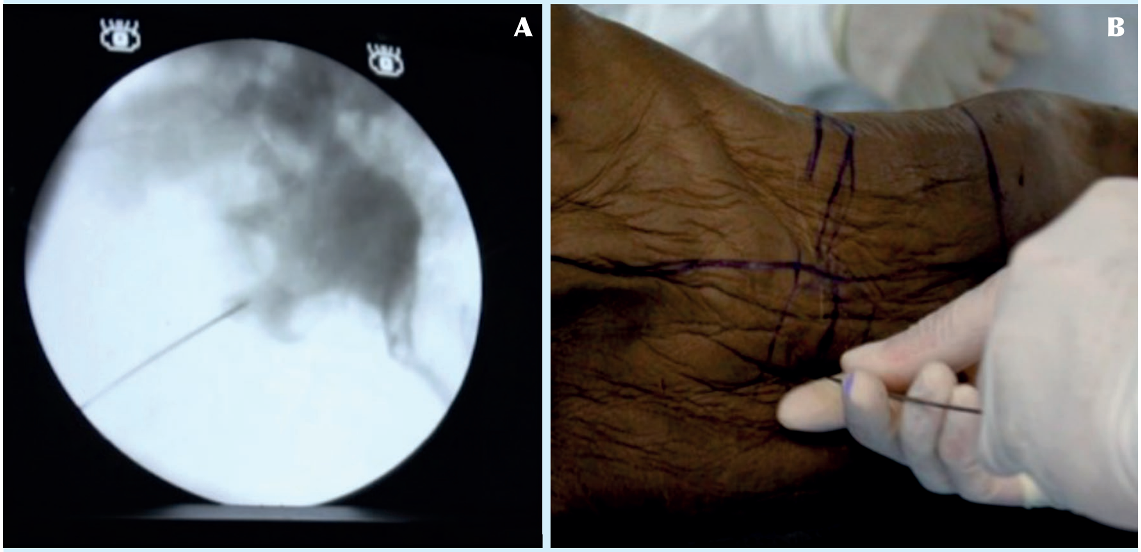

Figure 4. Renal puncture using the triangulation technique. **A)** Guided by fluoroscopy, the renal papilla is selected for access. **B)** The needle is inserted over the safety zone. Once the renal papilla is reached, access to the collecting system is confirmed by the return of fluid through the needle.

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participants. The percentage of successful punctures, the number of attempts per puncture and the radiation time were comparatively evaluated.

Statistical analysis

The Shaphiro-Wilk test was used to evaluate the normality of the quantitative variables. Continuous variables were described by mean and standard deviation (±SD). Categorical variables were described as frequencies and percentages. A comparative analysis was carried out between the characteristics of the initial punctures and the trial punctures. For quantitative variables, Student's t tests or Mann–Whitney U tests were used, selecting based on normality of distribution. For categorical variables, the c^2 test was used.

The statistical package SPSS for Windows, version 20.0 (IBM Corp. Armonk, NY) was used. Statistical significance was established at a value of $p<0.05$.

RESULTS

A total of ten kidneys from 6 human bodies were used. The cannulation of the ureters was obtained in 10/12 cases (83.3%). In one case, cannulation was not possible due to narrowing of the ureter that prevented retrograde pyelography. Therefore, 2 kidneys of the 6 cadaveric models were not punctured (16.7%).

The mean preparation time of the cadaveric model was 31 ± 8.4 minutes. The total number of punctures performed was 119, with 73 (61.4%) initial punctures and 46 (38.6%) trial punctures, with a mean of 12 ± 9.9 punctures per kidney and 6.4 ± 4.8 per calyx. The most frequently punctured calyx was the lower calyx (51.3%), followed by the middle calyx (48.7%). The superior calyx was not used for puncture due to the need for an intercostal puncture, which was not possible because of the reduced space present and the rigidity of the model. The overall puncture success rate was 50.4% (60/119), the mean radiation time was 1.3 ± 0.8 minutes. **Table 1**

In the comparative analysis, it was found that the success of the initial punctures was 41% (30/73) v. 65.2% (30/46) of the trial punctures ($p < 0.01$). In the former, a mean of 2.4 ± 1.2 attempts per puncture was obtained v. 2.0 ± 0.85 attempts in the latter ($p = 0.03$). The fluoroscopy time in the initial punctures was 1.49 ± 0.95 and in the trial ones it was 1.07 ± 0.52 minutes ($p < 0.01$), being significantly higher in the former. There were no differences in the distribution of punctured calyces ($p = 0.49$). **Table 2**

Table 1. General characteristics of the study population

Variables	n (%) or media ± DS
Characteristics of the models	
Human body models	6
Preparation time (minutes)	31 ± 8.4
Punctured kidneys	10/12[1] (83.3%)
Derived ureters	10/12[2] (83.3%)
Characteristics of the procedure	
Participants (Urology residents)	4
Total punctures	119
Kidney punctures	12 ± 9.92
Calyx punctures	6.4 ± 4.8
Punctures per resident	29.7 ± 9.5
Initial punctures*	73/19 (38.6%)
Test punctures	60/119 (50.4%)
Punctures attempts	2.25 ± 1.1
Fluoroscopy time (minutes)	1.3 ± 0.8
Puncture site	
Medium calyx	58/119 (48.7%)
Lower calyx	61/119 (52.3%)
Upper calyx	-

[1] Two ureters were not cannulated, so retrograde pyelography was not performed.

[2] Two ureters required bladder detachment and extravesical cannulation.

*Advice o evaluation of a trained physician (>100 procedures)

Table 2. Comparison of initial renal puncture and cadaveric model test of Urology residents

Variables	Initial puntures (n = 73)	Test punctures (n = 46)	p value
Puncture characteristics			
Punctures per resident (media ± DS)	18.25 ± 6.5	11.5 ±3.3	0.11[1]
Successful punctures (%)	30 (41)	30 (65.2)	<0.01[3]
Puncture attempts (media ± DS)	2.4 ± 1.2	2 ± 0.85	0.03[2]
Fluoroscopy time (minutes) (media ± DS)	1.49 ± 0.95	1.07 ± 0.52	<0.01[2]
Puncture site			
Medium calyx (%)	35 (47.9)	22 (47.9)	0.49[3]
Lower calyx (%)	38 (52.1)	24 (52.1)	0.49[3]
Upper calyx (%)	--	--	NA

[1] U Mann-Whitney to test non-parametric continuous variables.
[2] t Student test to continuous variables with normal distribution.
[3] χ^2 test to categorical variables.

DISCUSSION

Obtaining percutaneous renal access continues to be a challenge for urologists, especially residents. Access represents one of the most complex steps in PCNL, requiring a long learning curve and, therefore, a higher need for practice to obtain a level of training necessary for patient safety. The use of training models is a viable option in the training of trainees, increasing confidence, and transferring skills to real in vivo patient cases.[7,8,11,12]

It is estimated that 69.6% of urologists perform percutaneous procedures on the kidney. In the United States, only 11% of urologists who performed PCNL performed percutaneous access, with the interventional radiologist being the main performer of access.[5]

For a long time, a gradual and progressive teaching model has been used for the acquisition of surgical skills, through periodic observation and subsequent practice on the patient. However, due to the increase in medical-legal problems, economic-financial pressures and the constant advancement of technology, this conventional teaching method has undergone significant changes.[13] To this end, various training simulators have been proposed with the aim of safely and effectively developing the surgical skills necessary for the in-vivo patient surgery scenario. A reduction in learning curves, surgical times, and complications has been demonstrated.[7,14]

The learning curve for obtaining percutaneous renal access is not well established in literature. In the case of PCNL, some proficiency measures have been proposed, such as the stone-free rate, radiation time, rate of successful punctures, and complications.[15] In the study conducted by Allen et al, the proficiency parameter was fluoroscopy time during the procedure. They determined that the learning curve is achieved after 60 cases and excellence after 115 procedures, evaluated by significantly reducing radiation time.[16] In another study, it was reported that urology residents gained the confidence to perform this procedure after 21.2 ± 4.5 accesses, concluding that performing >24 percutaneous accesses during residency could improve the safety and results of surgery once graduated.[17]

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Currently, few models have been developed for urological training. There are two types of simulators: inanimate and virtual reality. Inanimate models can be biological and non-biological.[18] Biological models use different animal kidneys to recreate the anatomy of the puncture site. They are low-cost models. Porcine or bovine kidneys wrapped in foam, silicone, chicken breast plate, or a full-thickness skin covering are often used.[19] They have the disadvantage of absent respiratory movements. These animal models allow a simulator like to the human body, with the porcine model being the one that most closely resembles the anatomy of the human kidney. However, it still has important differences with respect to human anatomy.[20] Non-biological models are usually prototypes of different synthetic materials usually designed by 3D printing.[19]

Virtual reality simulators allow you to recreate an environment like to the one presented to the patient, through the projection of computer-generated images. It allows a stress-free experience, simulates breathing movements, and has been shown to reduce the learning curve. Experience in the field of urology is limited. Most of the literature regarding virtual reality training is directed at gastrointestinal endoscopy, laparoscopic surgery, and ureteroscopy.[21,22] To date, few virtual reality simulators for percutaneous renal access have been validated for the acquisition of basic skills for this procedure. The PERC Mentor™ is a virtual reality model that simulates fluoroscopy-guided percutaneous renal puncture. It was shown to have significantly reduced fluoroscopy time, reduced complications, and increased the percentage of successful punctures.[23] Mu Y et al described an augmented reality simulator for ultrasound-guided percutaneous renal access.[24] It was shown to reduce procedure time and improve the percentage of successful punctures. However, these simulators have the disadvantage of being expensive and of limited availability. In addition, it presents important differences with respect to the consistency of the tissue and human anatomy.[23,24] Despite exhaustive efforts, currently there is no evidence on the use of the simulator and its correlation with the acquisition of surgical skills on the in-vivo patient.[18,23,24]

Cadaveric models have been another attractive option for the training of urologists and other surgical specialties. To date, only one study has been published evaluating the use of a cadaveric model for ultrasound-guided percutaneous puncture of the kidney. The results obtained were very promising, with high satisfaction rates and great resemblance to *the in-vivo* patient.[25] In another study conducted by Castle et al, they evaluated a cadaveric model for puncture training, radiofrequency needle placement, and tumor ablation in kidney, which showed promising results.[6] Despite the great similarity to the *in-vivo* body, the need for specialized infrastructure for the preparation and maintenance of cadavers is a limitation in these models.[17,26]

Our study has some limitations, starting with being a preclinical experimental study. The clinical utility of the model has not been evaluated and the potential benefit it may provide when transferring skills to a patient in in vivo trans-operative scenarios is unknown to date. Another limitation is the exposure of residents to radiation produced by fluoroscopy. Although fluoroscopy continues to be the most widely used imaging technique, ultrasound has gained ground in recent years, and is considered an attractive option to reduce radiation exposure. Studies comparing the efficacy between fluoroscopy versus ultrasonography can provide results of great importance. The COVID-19 pandemic was also a limitation due to the decrease in the availability of bodies, laboratory hours, and number of participants.[27]

Prospective studies are recommended to validate the clinical utility of the human body model for percutaneous renal access training for urologists' trainees.

CONCLUSIONS

The proposed training model is a useful and reproducible tool, with the potential to develop surgical skills for renal access in percutaneous procedures for the urologist trainee. Radiation exposure among practitioners is a disadvantage that must be taken into consideration.

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