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ORIGINAL ARTICLE

A new porcine training phantom for percutaneous nephrostomy insertion

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Abstract

Background: The aim of the study was to create a simple phantom for radiology trainees to develop skills to perform a percutaneous nephrostomy, using a combination of ultrasonography and fluoroscopy. **Methods:** A porcine kidney was tied off at the renal pelvis and was submerged in a gelatine-based phantom. The renal collecting system was accessed under ultrasonographic guidance with an 18G or 21G needle, the renal collecting system was opacified with iodinated contrast medium, wire inserted, and a 5 Fr pigtail was inserted under direct fluoroscopy. **Results:** The porcine model was used to place several nephrostomies, and key steps such as ultrasonography-guided caliceal puncture, renal collecting system opacification, wire and catheter manipulation can be performed repeatedly. **Conclusions:** A porcine–gelatine phantom is a simple, cheap and useful training tool to provide nephrostomy training. This not only provides repeated familiarization of technical steps and psychomotor skills but also allows trainees to lay robust interventional groundwork without jeopardizing patient safety.

Keywords: *nephrostomy; simulation; interventional; urology; radiology*

Introduction

Training in interventional radiology follows an apprenticeship model with increasing exposure to procedures in a stepwise fashion. Learning curves are steep and nephrostomy can be challenging given the wide scope of presentations in different patients. This may range from a grossly dilated system to a non-dilated system. These patients often come with risk factor considerations such as obesity, shock and/or respiratory distress. For these reasons, most nephrostomy procedures are performed under image guidance because this allows accurate assessment and localization of the kidney. Although the Royal College of Radiologists curriculum in the UK does not indicate that a set number of procedural nephrostomies need to be performed to achieve competency, many UK trainees (including interventional radiologists) are trained through an apprenticeship model whereby successful training adopts a competency-based sign off approach.[1] Initially, this may begin with procedural observation with gradual progression towards direct and indirect supervision, ultimately reaching independence. This is educationally known as mastery, which is expected as one reaches the level of an interventional radiology consultant.[2] The trainees should first acquire basic interventional skills in an environment that limits the risk to patients.

Simulation of procedures using animal and artificial phantoms as part of basic skills workshops has been shown to be an effective educational tool, increasing confidence and competence.[3,4] Commercially available phantoms used by industry are expensive. Thus, a shift towards gelatine-based phantoms has become increasingly popular due to their low cost and high reproducibility features. However, although these phantoms may provide adequate comparisons of in situ simulation, these too may come with cultural and logistical challenges.[5] To date, there are no easily reproducible models available in addition to the methods described previously by Rock et al.[6] Therefore, we attempted to build on this model with involvement of a simple biological kidney. This article describes a simple four-step guide, from shop to table using readily available materials for interventional radiology trainees to master steps in percutaneous nephrostomy placement.

Materials and methods

Phantom creation

We adopted a simple four-step process for the construction of the phantom. Several articles describe ultrasonography-guided phantom creation, and a gelatine model with psyllium husk is favoured, as reported by Bude et al.[7] The model was simulated as if the patient is lying prone with the kidneys situated at either side of the flanks.

Step 1. Gathering materials

Materials are gathered including a 3-L plastic container, 15 sachets of gelatine (12 g per sachet) or vegetable gelatine substitute, a tub of psyllium husk, baking paper or aluminium foil, a porcine kidney from the butcher or market (Fig. 1A), an elastic band and water. Baking paper or aluminium foil is used to line the plastic tub, allowing simple disposal of the phantom once used.

Step 2. Base construction

Five sachets of gelatine are added to 300 mL of boiling water followed by stirring and whisking until all gelatine granules are dissolved. Then, 10 g of psyllium husk is added and stirred until the fluid becomes viscous. This is cooled for 1 h in a refrigerator.

Step 3. Visceral construction

The renal pelvis is held under flowing tap water in attempt to dilate the renal collecting system and an elastic band is tied around the renal pelvis (Fig. 1B). The dilated kidney is then placed on the gelatine base (Fig. 2).

Step 4. Subcutaneous layer

The final layer of the phantom is completed with 750 mL of water and 10 sachets of gelatine and 20 g psyllium husk. This is then poured over the kidney and base layer once partly cooled to submerge the kidney. If the kidney is not completely submerged, allow the phantom to cool and repeat step 2 until this is achieved and only the gelatine layer is seen (Fig. 3).

Fluoroscopic imaging

As nephrostomies are typically performed under imaging guidance, the phantom was placed on the interventional fluoroscopic table. The interventionalist along with the fluoroscopic operator typically don their personal radiation dosimeter ensuring their radiation exposure does not exceed the recommended radiation dose. Before screening, the kidney is located via ultrasonography and access is achieved through ultrasonography-guided puncture.

Results

The phantom demonstrated a realistic sonographic representation of a human kidney (Fig. 4). The calyces demonstrated minimal dilatation. A calyx was accessed with an 18G or 21G needle. Layers of tissue penetration can be felt, including a characteristic 'pop' as the collecting system is punctured. Contrast injection (Omnipaque 300 iodine) opacified the system, which also allowed mild dilatation of the system. A fine 0018 wire was screened into the renal pelvis, requiring careful manipulation to pass from calyx to pelvis (Supplementary Video 1). The access was then dilated, wire exchanged, and a small 5-Fr or 6-Fr pigtail catheter was inserted (see 'catheter pop', Supplementary Video 2). The loop was then formed in the renal pelvis to maintain the catheter position. A check nephrostogram was performed to confirm appropriate tube placement (Fig. 5). The cost-benefit ratio for training can be maximized by

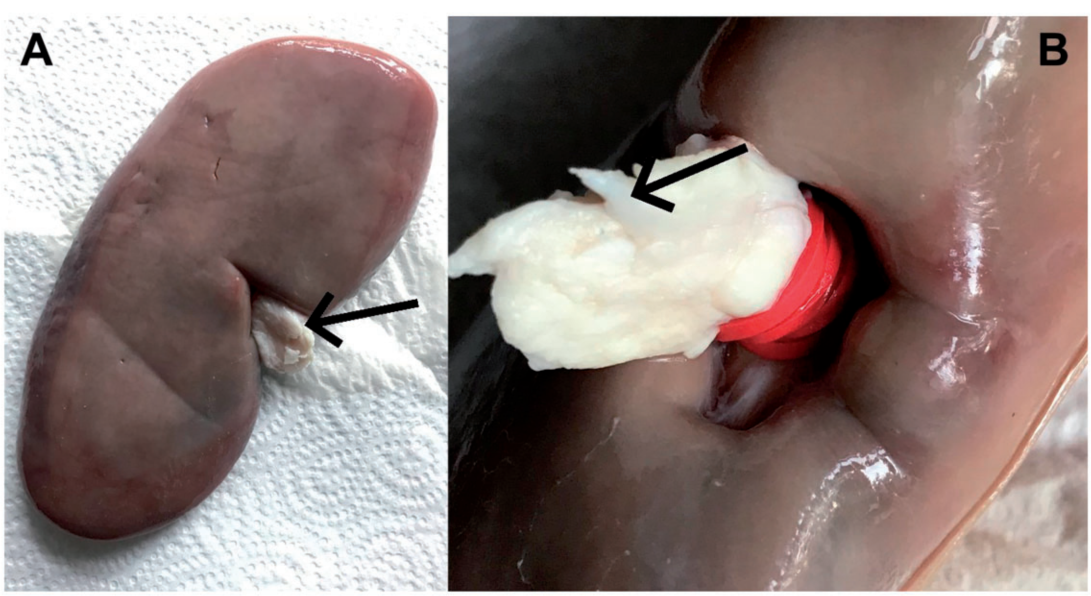

Figure 1. Porcine kidney. Arrow, partially intact ureter. (A) Lateral view of the porcine kidney. (B) Renal pelvis tied with an elastic band to maintain positive pressure after attempting to retrograde fill the pelvis with running water.

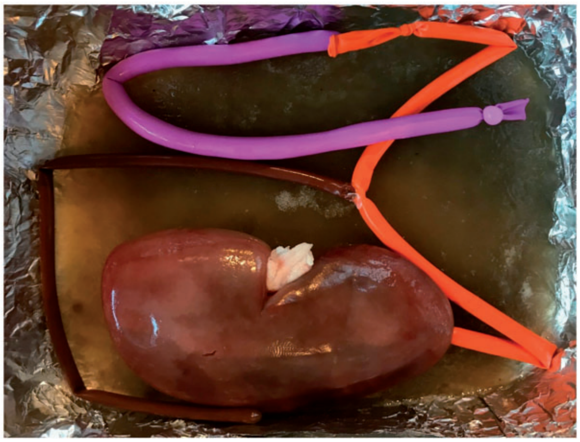

Figure 2. Kidney placed on the initial gelatine base layer. Fluid-filled long balloons formed to imitate the vasculature and for vascular puncture practise. These are contained in a plastic container wrapped in foil.

Figure 3. Completed gelatine phantom with the kidney and other structures submerged.

inserting multiple nephrostomy catheters within one phantom (Fig. 6; see 'guidewire2, Supplementary Video 3).

Discussion

This simple phantom builds on earlier work as described by Bude and Rock.[6,7] This model has the advantage of realistically simulating ultrasonography appearances, tissue planes, tissue 'pops', and fluoroscopic steps for nephrostomy placement.

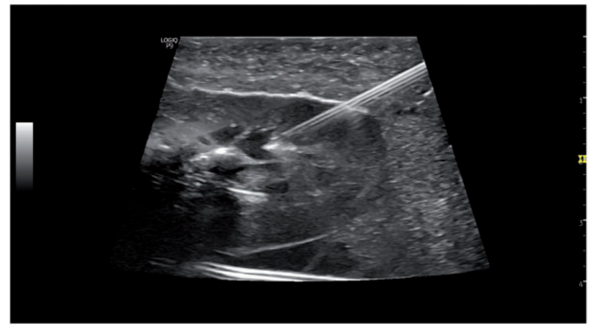

Figure 4. Ultrasonographic appearance of a mildly dilated renal collecting system.

The layering manufacturing process is important because otherwise the porcine kidney tends to float if these are constructed all at once. Chlorhexidine can also be added to preserve the reusability of the model, which can then be refrigerated for up to 1 week. Intra-operatively, the quality of nephrostomy insertion can be assessed by ultrasonographic correlation of placement as well as fluoroscopic contrast injection into the renal calyx or pelvis.

Despite the many benefits of using phantoms for training, there are inherent shortcomings and limitations in all artificially constructed phantoms. With regard to porcine kidneys, due to anatomic and pre-market preparation variations, each trainee may not receive exactly the same kidney morphology. However, this is representative of real-life procedures because similar morphology variations may also be present in humans as well as animal models. The quality of the kidney is also largely vender dependent; for example, some may provide the kidney with the ureter intact, whereas some may have the kidney pre-prepared before purchasing. One method to reduce this variability is to inform the vendor to keep the kidney clean and unprepared, minimizing the damage and unwanted preparation.

Porcine calices can be fine and thus this may not represent a true dilated system. However, trainees who are already proficient in fine-needle aspiration or performing biopsies should have sufficient skill to carefully puncture a fine 2-mm calyx with a 21G needle. In addition, because this is a non-living model, assessment of blood flow via duplex ultrasonography is not available. Also, the renal calyces are frequently demonstrated to be of similar fineness to nearby vasculature. Thus, the renal vein may be accessed unintentionally, resulting in rupture of the collecting system if the procedure is performed aggressively. However, in some ways, this is also an advantage of the model because careful

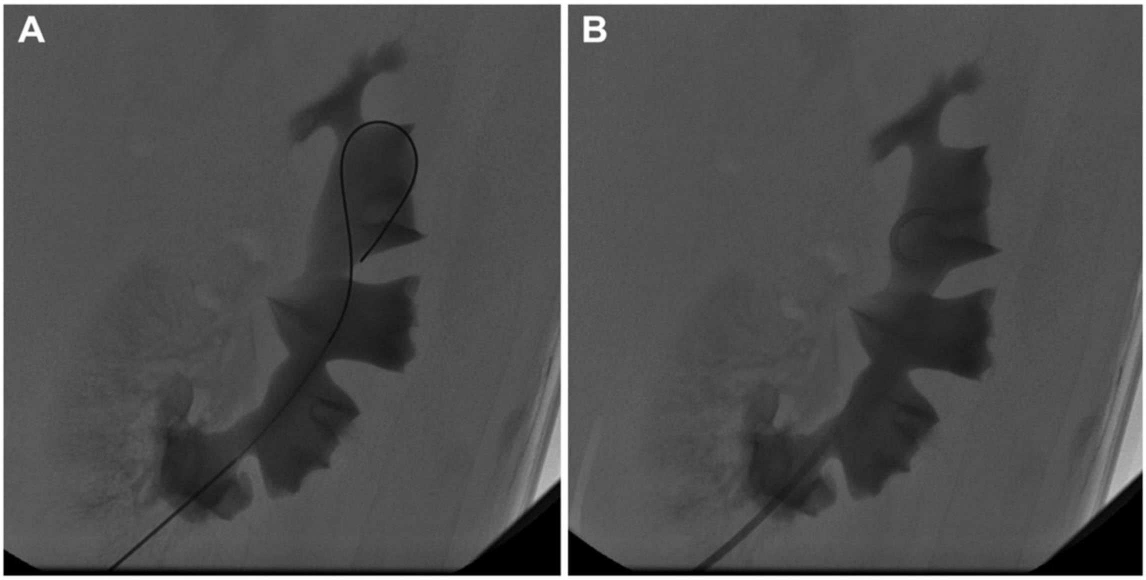

Figure 5. Nephrostogram of the renal pelvis. (A) Insertion of 0018 guidewire into the renal calyx. (B) Insertion of a nephrostomy pigtail catheter.

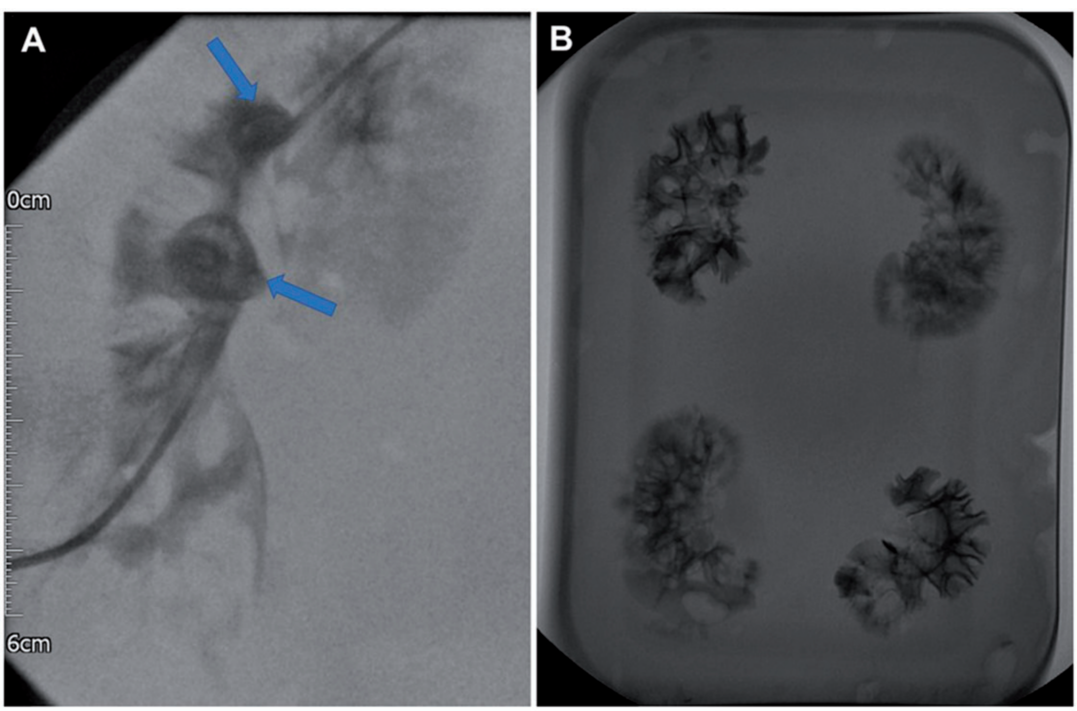

Figure 6. Examples of multiple uses of the same phantom. (A) Multiple pigtail catheter insertions into the same kidney indicated by the arrows. (B) Multiple kidneys within the same phantom container allowing multiple uses by different candidates/trainees.

needle handling, gentle 'puffs' of contrast and gentle wire manipulation are key to successful nephrostomy placement in real life, and therefore this phantom provides ample opportunity to develop these skills. Cultural sensitivities to animal products must also be considered not only for the operator but also for all caregivers who may be involved in the preparation and execution of the simulation. Although colour Doppler blood flow cannot be demonstrated in this phantom as described previously, this model nonetheless allows the trainee to build exquisitely fine techniques, including careful needle placement, ultrasonic demonstration of the needle tip and careful handling of the needle when transitioning for contrast injection or guidewire insertion.

This model was evaluated by an interventional radiology consultant with more than 10 years of experience and a radiology trainee. Although this model allows adequate dexterity training, we would require more practitioners and feedback to further optimize the phantom. A longitudinal evaluation may also be considered, i.e. evaluating trainees over the course of their training period. Further refinement of this model may also be improved by using different animal kidneys for training.

Medicolegal concerns may form a substantial portion of simulation training because considerations regarding videography, privacy and quality assurance laws must be met before conducting the simulation.[8] Some may approach nephrostomy training by performing the simulation first as the patient waits for their procedure, then subsequently performing the same procedure on a real patient once safe attempts have been made with the model. Although this is possible, this is not current practice, and it is vital that trainees are encouraged to receive continuous training rather than last-minute practise before performing the procedure in situ. Our simple proposed model allows trainees to have regular practise within a safe environment. As this is conducted 'offline', no harm is done to patients.

Phantom construction is simple and cheap. The total expenditure of ingredients is approximately £20 (approximately US$30). Furthermore, other conventional ultrasonography-guided phantoms can be incorporated into the same gelatine block; e.g. tubing for vascular access (as seen in Fig. 2), balloons for cyst aspiration or cholecystostomy simulation, and olives to simulate biopsy as described in the literature.[3]

Conclusion

This simple nephrostomy phantom realistically simulates key ultrasonographic and fluoroscopic steps in nephrostomy placement. This would allow further learning and development of interventional radiology or urology trainees to improve their skills in preparation for real-life radiologically assisted nephrostomy procedures in patients.

Conflict of interest

The authors have no conflicts of interest to declare.

Supplementary material

Supplementary Video 1. Guidewire1: insertion of 0018 guidewire into the renal pelvis. Available from: https://youtube.com/shorts/NLd9SiTmroU

Supplementary Video 2. Catheter pop: fluoroscopic capture of catheter insertion. Characteristic 'pop' on entry into the collecting system shown. Available from: https://youtube.com/shorts/JY_sxxILkII

Supplementary Video 3. Guidewire2: insertion of a second 0018 guidewire into the renal pelvis with the first nephrostomy catheter in situ. Available from: https://youtube.com/shorts/cBrKuBir6_I

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