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INTERVENTIONAL RADIOLOGY

LETTER TO THE EDITOR

Proposal for training: the educational value of a musculoskeletal embolization patellar tendinopathy model

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Dear Editor,

Model training presents significant advantages for training purposes in several key areas of musculoskeletal embolization. The model allows trainees to gain practical experience with the procedures, techniques, and equipment used in real-world scenarios. This hands-on practice is invaluable for building confidence and competence to find and treat neovessels. As we have seen recently,[1] detecting neovessels, which is a direct marker of the technical success of this treatment, is a key but challenging step in performing embolization and must be mastered to avoid inappropriate patient management.

The patellar tendinopathy pig animal model[2] provides a realistic environment for trainees to learn how to diagnose and treat neovascularization. This is particularly important for understanding the complexities and nuances of different degrees of neovessel visualization. In this study, we improved our understanding of the model and developed a classification for the evaluation of these neovessels during pre- and post-embolization angiographies. A Likert scale was used to evaluate the neovessels in our model (grade 0: no neovessels; grade 1: slight tumor blush equivalent to muscle enhancement; grade 2: marked tumor blush greater than muscle enhancement; grade 3: very marked tumor blush). Additionally, we examined associated vascular anomalies (arterial anastomosis, early venous return). These observations are detailed and illustrated in the portfolio (Figures 1 and 2) for the reader's reference. Based on this classification, this model allows for an expert and reliable angiographic evaluation of the effectiveness of the embolization agent used by comparing the neovessels before and after embolization.

During the past year, from 2023 to 2024, 24 angiographies were conducted on our pig patellar tendinopathy model, involving 12 pigs and 24 tendons. Tendinopathy induction involved injecting a total of 50 mg of type 1 collagenase per tendon under ultrasound guidance, using two syringes, each containing 25 mg at a concentration of 25 mg/mL. The injections were performed using 1-mL insulin syringes (G25 with attached needles) for precise and controlled delivery. On all the angiographies performed at D7, the presence of neovessels was noted. Across all the series performed, 5 had grade 1 neovessels, 8 had grade 2, and 11 had grade 3. Moreover, six had multiple arterial anastomoses and seven had early venous return (often in association). For reference, these described vascular anomalies can be associated with any grade of neovessels, sometimes masking their detection. This highlights the value of this model for training in identifying neovessels and then practice in treating them.

One of the key benefits of using an animal model lies in the tactile feedback it offers, which is crucial for learning how to manage resistance and understand the importance of quality injections, as we previously described,[1] in musculoskeletal embolization. This tactile feedback also aids in assessing reflux and making real-time adjustments, skills that are challenging to replicate in purely virtual or silicone-based environments. This hands-on experience may help to develop not only theoretical knowledge but also essential technical competence.

Although simulators represent the future of medical training, and some affordable options do exist, those specifically designed for high-fidelity embolization procedures remain expensive. Moreover, one of the issues with current simulators is their lack of fidelity to the

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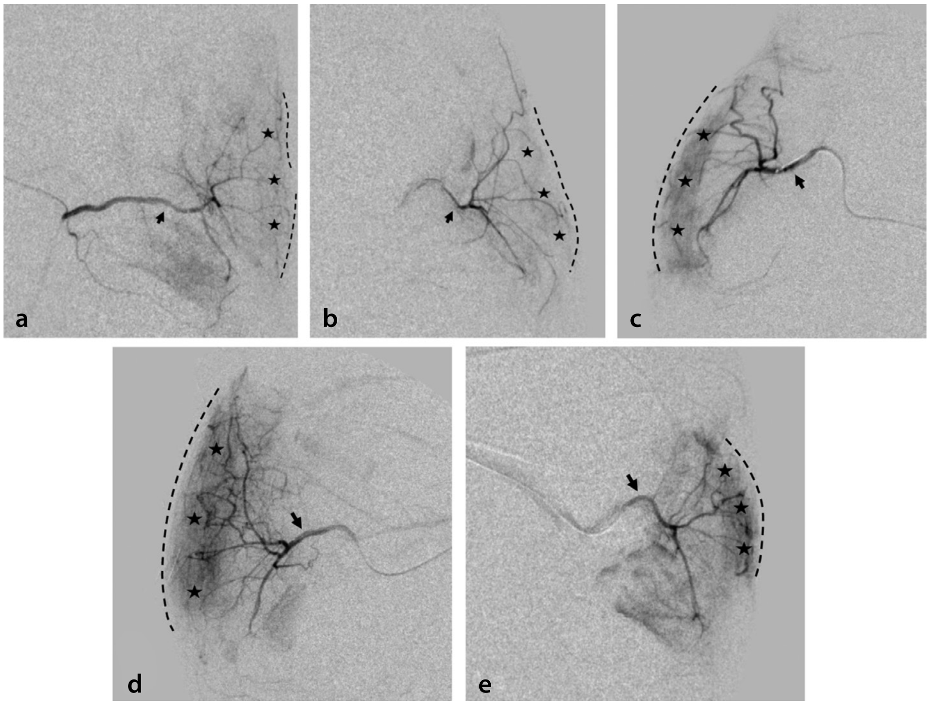

Figure 1. Evaluation of neovessels according to a Likert scale, grade 1 to 3. The dotted lines represent the anterior surface of the inflamed patellar tendon in these profile views from arteriographies performed 7 days after tendinopathy induction. The black arrows represent the genicular artery. Pictures **(a)** and **(b)** show grade 1 neovessels (black stars), which correspond to a slight tumoral blush equivalent to muscle enhancement. It is important to note the difference in enhancement compared with grade 2 **(c)** and grade 3 **(d, e)** neovessels, which exhibit significantly more pronounced enhancement.

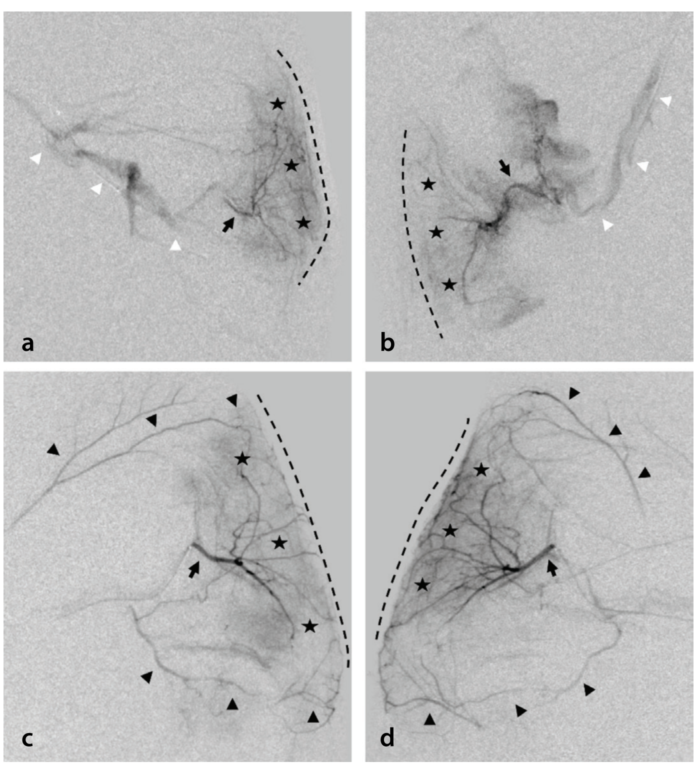

Figure 2. Evaluation of vascular anomalies associated with neovessels. Under the same conditions, images **a** and **b** represent an early venous return (white arrowheads). This early venous return can sometimes mask the appearance of neovessels, as seen in image **b** (grade 1) compared with image **a** (grade 2). Early venous return results in contrast agent leakage, making it difficult to adequately impregnate the arterial vascular network during injection. Images **c** (grade 1) and **d** (grade 2) illustrate arterial collaterals (black arrowheads), which are also important to identify. If not occluded, they continue to supply the neovessel bed, leading to treatment failure.

actual procedure, which limits their effectiveness. This makes purchasing a simulator a significant financial investment that may not deliver the expected training outcomes, further exacerbating the financial barriers for many programs.[3] By contrast, although using an animal model also incurs significant costs, it offers a highly realistic, high-fidelity experience that closely mimics human procedures, making it an invaluable tool for training.

Nevertheless, implementing an animal model from scratch involves considerable costs. For example, acquiring a refurbished C-arm capable of fluoroscopy and digital subtraction angiography for use with animals costs approximately €60,000. Additional expenses for model induction include ultrasound equipment (approximately €10,000) and needles for intrapatellar injections. Supplies for embolization, which are single use for each pig (introducer, guidewire, 4Fr catheters, 2.0Fr microcatheters, embolization particles), cost approximately €2,000 per procedure. The cost of housing for the animals for 1 week is approximately €1,000 per pig, including pharmacy costs (particularly for anesthesia coverage) and the purchase of operating room supplies (compresses, sterile drapes), which are approximately €300 per pig. Radiation shielding for the facility could add another €100,000. Although these costs may seem high, they are indicative and vary depending on the existing infrastructure at each institution.

However, the tactile feedback and intra-procedural experience provided by the animal model remain unparalleled, offering a training fidelity that current simulators cannot achieve. This model allows trainees to practice in a realistic environment, gaining practical skills in embolization that are directly translatable to clinical practice. As such, despite the costs, the animal model remains, until today, an invaluable tool for advanced training in musculoskeletal embolization.

Additionally, this animal model facilitates the continuous creation of new e-learning content (anatomical education, the classification of neovessels, and the inclusion of video recordings of angiograms) and can be employed for various educational purposes, such as anatomical dissections or managing hemorrhages in surgical training just before the sacrifice of the animal. Furthermore, an additional comparative study between traditional methods and this animal model could be useful to more objectively assess its educational effectiveness.

Standardized training is essential for maintaining high medical standards and ensuring the best possible outcomes for patients. We believe that the combination of theoretical e-learning with practical sessions on the animal model provides a balanced solution for acquiring in-depth knowledge and essential technical skills. This blended approach not only enhances the learning experience but also ensures the development and refinement of new techniques, ultimately leading to optimal patient outcomes. Overall, this model serves as an invaluable resource for medical training, providing a comprehensive and safe environment for learning in the field of musculoskeletal embolization.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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