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Development of a Low-Cost Kidney Model Using Tomatoes and Its Applicability in Anatomy Education

Desarrollo de un Modelo de Riñón de Bajo Costo Utilizando Tomates y su Aplicabilidad en la Enseñanza de la Anatomía

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SUMMARY: This study presents an innovative and cost-effective approach to kidney anatomy education by using tomatoes as a model to replicate the complex structures of the kidney. Traditional kidney models, while accurate, are often expensive and inaccessible for many educational settings. To address this, we propose using tomatoes, whose natural shape and internal texture closely resemble various anatomical features of the kidney. The methodology involves slicing tomatoes in specific ways to visualize kidney structures such as the renal cortex, medulla, pyramids, and vascular system. The results show that tomato-based models provide a highly accessible and tactile learning tool that enhances students' understanding of kidney anatomy. These models are easy to create, require no specialized tools, and allow for hands-on learning that improves retention and engagement. Moreover, the embryological similarities between the tomato's internal structure and the kidney's anatomy provide an intuitive way to explain developmental processes and blood flow. This study underscores the potential of low-cost, high-efficiency educational tools in medical training and suggests expanding the use of such models to other organs and scientific disciplines. By integrating simple, practical methods like these, anatomy education can become more inclusive and effective.

KEY WORDS: Kidney model; Anatomy education; Cost-effective models; Medical training; Innovative teaching tools.

INTRODUCTION

Understanding kidney anatomy is fundamental in medical education due to its vital physiological functions and complex internal structure. The kidney, being one of the largest and most functionally significant organs, presents challenges for learners who need to grasp its intricate details. Traditional kidney models, while accurate, are costly to produce, making them less accessible for many educational institutions and students. Therefore, there is a pressing need for more affordable yet effective methods to replicate kidney structures for educational purposes.

Recent studies have explored various innovative techniques to address the challenges of teaching complex anatomical structures like the kidney. Kim & Chae (2012) have identified the difficulties students face in mastering kidney anatomy and proposed solutions such as virtual reality (VR) and practical dissection experiences to enhance understanding. Sakellariou *et al*. (2009) further suggested incorporating haptic feedback and augmented reality to create a more interactive learning environment, while Seoung (2020) demonstrated the effectiveness of 3D-printed models in radiology education, showing their potential to improve comprehension of kidney structures. These studies underline the importance of integrating advanced technology and practical approaches to make anatomy education more engaging and effective.

Moreover, the exploration of cost-effective materials for educational models has gained attention. For instance, Mantica *et al*. (2021) and Clark *et al*. (2021) have shown the potential of using everyday items like tomatoes to create high-fidelity models for medical training. Tomatoes, due to their natural shape and texture, can mimic the kidney's anatomical features effectively, offering an accessible alternative to more expensive models. Yamazaki *et al*. (2023) also highlighted the benefits of 3D printing for creating

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customizable kidney models that provide a detailed learning experience, while Chung *et al*. (2016) developed educational software featuring detailed 3D models to aid in the learning process. These diverse approaches demonstrate the ongoing effort to develop models that are not only accurate but also economical and easy to produce.

This study focuses on an innovative approach to kidney model creation using tomatoes, leveraging their natural form and texture to simulate kidney structures. The advantages of tomatoes include their affordability, availability, and versatility, which allow them to represent different parts of the kidney effectively. When appropriately processed, tomatoes can serve as a practical educational tool, enabling students to gain a clearer understanding of kidney anatomy. Unlike traditional models, the tomato-based models do not require specialized tools or techniques, making them highly accessible.

Tomatoes have been effectively utilized as low-cost, realistic models in various medical training scenarios, such as percutaneous renal access and shave biopsy techniques (Clark *et al*., 2021; Mantica *et al*., 2021). Their pliable nature and varied shapes make them suitable for demonstrating surgical procedures and anatomical structures. This study aims to build on this foundation by detailing the process of creating a kidney model using tomatoes and exploring its application in educational settings. By doing so, it highlights the potential for developing cost-effective, high-efficiency educational tools that can significantly enhance anatomy education.

In this paper, we provide a comprehensive overview of the methodology for creating a kidney model using tomatoes, from the selection and processing of materials to their practical use in educational scenarios. We aim to demonstrate that these models not only offer economic advantages over traditional models but also provide an intuitive and effective learning experience. Through this study, we seek to contribute to the growing body of research focused on innovative and accessible approaches in medical education, emphasizing the importance of developing practical, affordable tools that improve learning outcomes.

MATERIAL AND METHOD

First, fresh tomatoes were prepared (Fig. 1A). To replicate the structure of the kidney, the tomatoes were sliced horizontally through the middle (Fig. 1B). This initial cut reveals the internal structure of the tomato, allowing for more precise cuts in subsequent steps. Next, from the cut surface, the tomato was sliced again horizontally, slightly offset from the center (Fig. 1C). This process results in a cross-section of the tomato that can be used to visually explain various anatomical structures of the kidney (Fig. 1D). This entire procedure leverages the natural structure of the tomato to clearly illustrate the anatomical features of the kidney. This method enabled us to create a simple yet effective educational tool, demonstrating its potential as an economical and practical model for anatomy education.

RESULTS

In this study, we developed a model using tomatoes to visually explain the structure of the kidney. By using cross-sections of tomatoes, we recreated each part of the kidney, allowing students to easily visualize the anatomical structure of the kidney. The overall diagram shows a series of steps that visually represent the kidney's structure by cutting the tomato. Each stage includes processes that utilize tomatoes to explain the various anatomical structures of the kidney. This greatly aids students in intuitively understanding the complex structure of the kidney in anatomy education.

In Figure 1A, we labeled each structure on the tomato cross-section. The Renal cortex is represented by the outer part of the tomato, while the Renal medulla is indicated by the darker inner part. The Renal papilla is marked at the end

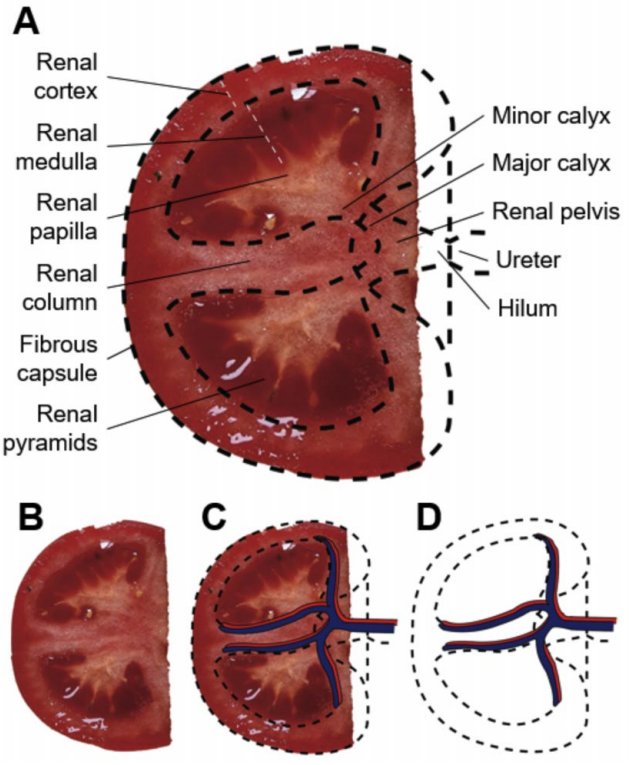

Fig. 1. A. Fresh tomatoes prepared for the experiment. B. Tomatoes sliced horizontally through the middle. C. Tomatoes sliced again horizontally, slightly offset from the center. D. The final cross-sections of the tomatoes showing both sides of the cuts.

of the Renal medulla, and the Renal column is shown between the sections of the Renal medulla. The Fibrous capsule is represented by the skin of the tomato, and the Renal pyramids are depicted as pyramid-shaped structures within the Renal medulla. Additionally, structures such as the Minor calyx, Major calyx, Renal pelvis, Ureter, and Hilum are connected with lines and labeled accordingly. Figure 1B shows the cross-section of the tomato before any lines are drawn, representing the natural state of the tomato and serving as a baseline for marking the structures in subsequent stages. In Figure 1C, the structures labeled in stage A are further enhanced by adding the Renal artery and Renal vein. These are represented with blue and red lines to visually depict the blood vessel structures and demonstrate the blood flow within the kidney's vascular system. Figure 1D shows the cross-section of the tomato with all the structures and blood vessels represented solely by lines. This helps to clearly understand the positions and shapes of the structures, allowing students to visualize the actual structure of the kidney more effectively.

DISCUSSION

In this study, we developed a model using tomatoes to visually explain the anatomical structure of the kidney, providing a method that helps students easily understand the complex structure of the kidney. This approach offers several important educational and economic advantages.

Firstly, the kidney model made from tomatoes is economical. Traditional kidney models require expensive materials and complex manufacturing processes, whereas tomatoes are inexpensive and readily available. This can significantly reduce the cost burden for educational institutions, providing more students with the opportunity to receive high-quality anatomy education. Additionally, the tomato-based model can be easily created with simple cutting and surface processing, making it accessible for anyone to construct.

Secondly, the kidney model made from tomatoes enhances both visual and tactile learning. Through the process of cutting and observing the tomato, students can understand the structure of the kidney more intuitively. This hands-on learning approach increases student engagement and helps them retain the material for a longer period. Additionally, the natural internal structure of the tomato closely resembles the tissue of an actual kidney, maximizing the educational effectiveness.

Thirdly, this study enhances the educational applicability through embryological similarities. The structure of the tomato and the anatomical structure of the kidney share many embryological similarities, greatly aiding students in understanding the developmental process of the kidney. For example, the internal branching structure of the tomato is similar to the vascular branching structure of the kidney, making it easier to explain the blood flow and structural relationships within the kidney.

Recent studies have explored innovative approaches to enhance understanding of renal anatomy and vasculature. A semi-immersive 3D sketching interface for vascular structures has been developed to support anatomy education, allowing educators to create and explain complex spatial relationships of interlinked vascular structures (Saalfeld *et al*., 2016). Additionally, corrosion casts of renal vasculature have been employed in undergraduate teaching, enhancing students' spatial visualization skills and understanding of complex vascular relationships (Shrivastava *et al*., 2020). These approaches demonstrate the potential of innovative teaching methods to improve comprehension of renal anatomy and vasculature.

Lastly, the use of tomato-based models has the potential to be expanded for various educational purposes beyond kidney anatomy. For instance, it can be applied to create models of other organs such as the liver, lungs, and heart, thereby broadening the scope of anatomy education. Additionally, this approach holds potential for use in other scientific fields such as biology, geography, and chemistry, demonstrating its versatility and wide-ranging applicability.

In conclusion, the tomato-based kidney model serves as a low-cost, high-efficiency educational tool that can significantly enhance the quality of anatomy education. It is essential to further evaluate and improve the educational effectiveness of this model, exploring ways to utilize it as a learning tool for various anatomical structures. Through these efforts, we aim to increase the accessibility of anatomy education and contribute to creating an environment where more students can receive high-quality education.

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RESUMEN: Este estudio presenta un enfoque innovador y rentable para la enseñanza de la anatomía renal mediante el uso de tomates como modelo para replicar las complejas estructuras del riñón. Los modelos tradicionales de riñón, si bien son precisos, suelen ser costosos e inaccesibles para muchos entornos educativos. Para abordar esto, proponemos utilizar tomates, cuya forma natural y textura interna se asemejan mucho a varias características anatómicas del riñón. La metodología implica cortar los tomates de formas específicas para visualizar las estructuras renales, como la corteza renal, la médula, las pirámides renales y el sistema

vascular. Los resultados muestran que los modelos basados en tomates proporcionan una herramienta de aprendizaje muy accesible y táctil que mejora la comprensión de los estudiantes sobre la anatomía renal. Estos modelos son fáciles de crear, no requieren herramientas especializadas y permiten un aprendizaje práctico que mejora la retención y la participación. Además, las similitudes embriológicas entre la estructura interna del tomate y la anatomía del riñón proporcionan una forma intuitiva de explicar los procesos de desarrollo y el flujo sanguíneo. Este estudio destaca el potencial de las herramientas educativas de bajo costo y alta eficiencia en la formación médica y sugiere ampliar el uso de dichos modelos a otros órganos y disciplinas científicas. Al integrar métodos simples y prácticos como estos, la educación en anatomía puede volverse más inclusiva y efectiva.

PALABRAS CLAVE: Modelo de riñón; Educación en anatomía; Modelos rentables; Formación médica; Herramientas de enseñanza innovadoras.

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