American Journal Of Biomedical Science & Pharmaceutical Innovation

VOLUME Vol.05 Issue09 2025
PAGE NO. 11-13
DOI 10.37547/ajbspi/Volume05Issue09-02

Comparative Analysis Of Computed Tomography And Magnetic Resonance Imaging Data With Anatomical Specimens To Clarify The Topography Of The Retroperitoneal Organs

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Received: 28 July 2025; **Accepted:** 24 August 2025; **Published:** 26 September 2025

Abstract: Accurate knowledge of the topographic and anatomical features of the retroperitoneal space (RPS) is critical for diagnosis and surgical planning. Modern imaging techniques, such as computed tomography (CT) and magnetic resonance imaging (MRI), have become the gold standard in clinical practice; however, their compliance with classical anatomical concepts requires constant verification. Objective: To conduct a comparative analysis of CT and MRI data with the anatomical structure of RPS organs on specimens to clarify their topography and assess variability. Materials and Methods: An analysis of 50 CT and 30 MRI studies of patients without RPS pathology, as well as macroscopic specimens from 15 adult cadavers, was conducted. The topographic relationships of the kidneys, adrenal glands, large vessels (aorta, inferior vena cava), pancreas, and duodenum were assessed. Results: It was established that modern high-resolution imaging methods (contrast-enhanced CT, MRI with fat-suppressed sequences) reliably depict the anatomical structures of the renal pelvis. Cases of clinically significant variability were identified: atypical branching of the renal arteries (18% of cases according to CT angiography), retroaortic position of the left renal vein (4%), which fully correlated with the data of anatomical specimens. However, fascial relationships and thin nerve plexuses are reliably visualized only on specimens. Conclusion: The integrated use of CT/MRI data and classical anatomical examination on specimens provides the most complete understanding of the topography of the renal pelvis. The integration of virtual 3D models reconstructed from tomography data into the educational process of medical universities helps to overcome the limitations associated with the shortage of cadaveric material and improve the effectiveness of student training in topographic anatomy.

Keywords: Retroperitoneal space, topographic anatomy, computed tomography, magnetic resonance imaging, anatomical preparations, medical education.

Introduction: The retroperitoneal space (RPS) is a complex anatomical region containing vital organs (kidneys, adrenal glands, pancreas, and part of the duodenum), major vessels (aorta, inferior vena cava), and nerve plexuses [1]. The topographic anatomy of the RPS is fundamental for diagnosing diseases, planning, and performing surgical interventions in urology, abdominal, and vascular surgery.

For centuries, cadaveric dissection has been the "gold standard" for studying anatomy. However, in the modern reality, access to anatomical specimens for students is limited due to ethical, economic, and sanitary considerations [2]. At the same time, imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI) provide noninvasive and highly accurate means of visualizing human body structures in vivo [3]. The relevance of this study stems from the need to verify data obtained using modern imaging methods by comparing them with classical anatomical standards. Recent studies highlight the importance of such comparative analysis for identifying individual anatomical variability, which can have critical clinical significance [4, 5].

The objective of the study was to conduct a comparative analysis of CT and MRI data with anatomical specimens to clarify the topographic relationships of organs and structures in the retroperitoneal space and to assess the potential for integrating these data into medical school curricula.

METHODS

A comparative study was conducted, including two components: imaging data analysis and anatomical examination.

Clinical group: Data from 50 patients who underwent multislice CT (MSCT) of the abdominal organs and pelvic organs with intravenous contrast enhancement and 30 patients who underwent MRI using a 1.5 T magnetic field strength machine were retrospectively analyzed. Inclusion criteria: no documented pelvic organs pathology according to the studies.

Anatomical group: Fifteen pelvic organs macroscopic specimens prepared from adult cadavers (age at death, 45-75 years) with no significant pathological changes in this area were analyzed.

Analysis methods: The position, shape, size, and relationships of the kidneys, adrenal glands, pancreas, aorta, inferior vena cava (IVC), and their major branches were assessed for CT and MRI data. Particular attention was paid to the fascial layers (retroperitoneal fascia, Gerota's fascia, and Toldt's fascia). A similar assessment was performed on anatomical specimens, with the ability to perform layer-by-layer dissection to examine the fascial layers and neural structures.

Statistical analysis: A descriptive comparison of the obtained data was conducted. Qualitative differences and correlations between anatomical variants were recorded.

RESULTS

A comparative analysis revealed a high degree of agreement between CT/MRI data and anatomical specimens regarding the main organs of the renal pelvis.

Visualization of parenchymal organs: The contours, sizes, and positions of the kidneys and adrenal glands on axial, coronal, and sagittal CT and MRI reconstructions were completely consistent with those on the specimens. MRI, due to its improved soft tissue contrast, more accurately visualized the renal cortex and medulla, which correlated with the macroscopic appearance on the sectional view.

Vascular anatomy: CT angiography accurately depicted the course of the abdominal aorta, IVC, and their main branches. Similar anatomical variations were identified on the specimens and CT reconstructions: the presence of accessory renal arteries (18% of cases) and the retroaortic position of the left renal vein (4% of cases), which is important presurgical information. Fascial and cellular spaces: CT and MRI data allowed differentiation of the main fascial layers (anterior and posterior paranephric tissue), especially in the presence of a pathological process (e.g., paranephritis). However, subtle fascial relationships, particularly in the area of fascial fusion, were clearly visible only with layered dissection.

Nerve plexuses: Large nerve trunks (e.g., the celiac plexus) were sometimes visualized on MRI, but their detailed topography was only accessible for study in anatomical preparations.

Thus, imaging techniques are ideal for studying "volumetric" topography and vascular variations, while preparations remain indispensable for understanding fine connective tissue and neural structures.

DISCUSSION

The obtained results are consistent with current research data. The work of Standring S. (2021) emphasizes that CT and MRI have become the main methods for studying antemortem anatomy [1]. A study by Smith J. et al. (2020) demonstrated that 3D reconstructions based on CT data can predict individual patient anatomical features preoperatively with up to 95% accuracy [4]. Our data on the incidence of accessory renal arteries (18%) are also consistent with literature data, which range from 15% to 25% [5].

Role in the education of medical students.

The main problem of modern anatomy education is the lack of time and cadaveric material [2]. The results of our study demonstrate that the integration of CT and MRI data into the educational process is not just a supplement, but a necessity.

Bridge technology: CT and MRI serve as a "bridge" between two-dimensional atlases and three-dimensional anatomical preparations. Students can study topography on live, non-invasively acquired images.

Visualization of Variability: Tomography allows for the demonstration of the full breadth of anatomical variability, which cannot be demonstrated with a limited number of specimens.

Clinical Integration: Working with CT and MRI from the first year prepares students for the interpretation of diagnostic images in future clinical practice. A study by Paech D. et al. (2019) showed that students trained using MRI atlases demonstrated better results in recognizing structures in diagnostic images [6].

The most promising direction is the creation of interactive 3D atlases based on real tomographic data that can be used in simulation classes. This helps compensate for the lack of specimens and provides students with a safe and effective learning environment [7].

Limitations of the study: A limitation is the relatively small size of the anatomical sample. In addition, tomographic methods do not allow for a full study of the color and tactile characteristics of tissues, which is an important element of classical dissection.

CONCLUSION

The study confirmed that high-resolution CT and MRI data are highly accurate tools for studying the topography of the retroperitoneal space, particularly with regard to the position of organs and vascular structures. However, classic anatomical preparations remain indispensable for a thorough understanding of fascial and neural relationships.

Therefore, modern teaching of topographic anatomy should be based on the synergy of two approaches: traditional dissection and work with radiographic data. The integration of CT and MRI into the medical school curriculum, including the creation of virtual 3D atlases and simulators, significantly improves the quality of training for future physicians, developing a holistic and clinically oriented understanding of human anatomy.

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