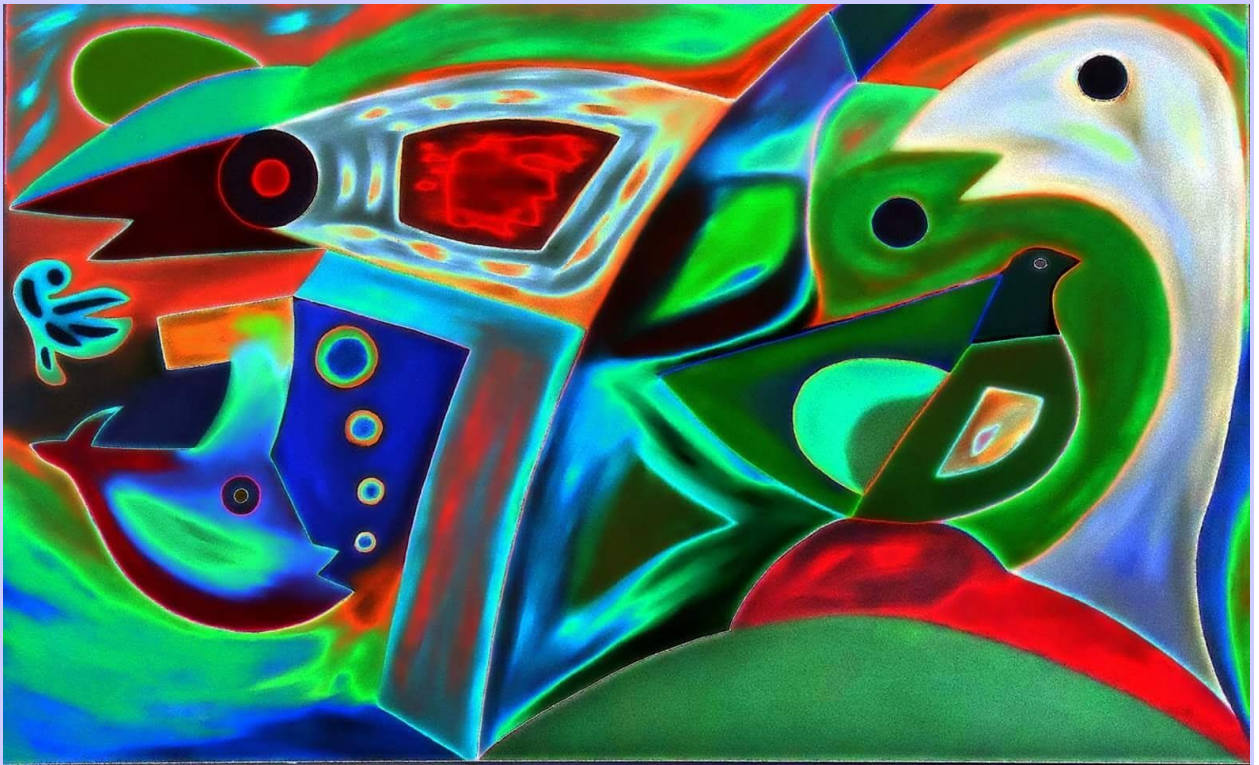


Journal of Digital Art & Humanities



ISSN 2712-8148

Vol.7 Iss.1

June 2026

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Historical Challenges of Tomography

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Received 23.04.2025/Revised 23.05.2025/Accepted 26.05.2025/Published 26.06.2026

https://doi.org/10.33847/2712-8148.7.1_1

Abstract. The study examines the challenges of tomographic research in the 19th and 20th centuries, which significantly influenced healthcare and medicine. It highlights the role of Russian (Soviet) scientists in developing the theoretical foundations of tomography and presents characteristics of original domestic tomograph designs. The paper covers key events in the history of tomography and associated research methods. A significant part is devoted to analysing design flaws of tomographic equipment used in healthcare. The research draws on historical publications and periodical press materials. To study these sources, the authors employed data analysis, synthesis, generalisation, and systematisation, as well as the principles of objectivity and historicism. This approach enabled the integration of the obtained data into scientific circulation. Paper analysed the applications' challenges of three types of tomographs. It also discusses scientists' efforts to improve tomographs based on new theoretical approaches and original concepts. Key findings: continuity of scientific achievements from 19th–20th century works to modern technologies (PCCT, AI, phase contrast); systematised historical data (chronology, contributions, technical solutions); and a reproducible analytical framework for assessing scientific progress. The key conclusion is that domestic and international studies in this period laid the foundations for the development of tomography theory and practice. They were an effective, non-invasive method for layer-by-layer human examination. These studies initiated further trends for innovative tomographic solutions.

Keywords: history of medicine, tomography theory, tomographs, methods of layer-by-layer, examination of human organs and body parts, scientists, radiological engineers.

1. Introduction

The historical development of tomographic imaging, long overshadowed by the clinical debut of computed tomography (CT) in the 1970s, has recently garnered renewed international scholarly attention. While the core Russian study acknowledges the contributions of Soviet scientists, a growing body of non-Russian literature emphasizes that the theoretical and technical genesis of tomography was a truly global, multi-generational endeavor rooted in early 20th-century mathematics and engineering [1–3].

The foundational mathematical framework for all modern tomographic reconstruction was laid by the Austrian mathematician Johann Radon. In his seminal 1917 paper, Radon demonstrated how a function could be determined from its integrals along certain manifolds—a concept that became the mathematical backbone of CT, positron emission tomography (PET), and single photon emission computed tomography (SPECT) [4,5]. Radon's work remained largely unnoticed by the medical community for decades, yet it provided the theoretical key to non-invasive, layer-by-

layer human examination [1]. The Radon transform remains central to tomographic reconstruction algorithms [6].

The translation of Radon's mathematics into practical engineering began in the early 1920s. On June 3, 1921, the French physician André Bocage filed a patent describing synchronous, opposite movement of the X-ray tube and film to render a single plane sharply in focus [7]. Independently, Jean Kieffer conceived an "X-ray focusing machine" in 1928 (patented 1934) [8]. Shortly thereafter, the Dutch radiologist Bernard George Ziedses des Plantes published his "planigraphy" method in *Acta Radiologica* (1932), demonstrating one of the first clinical implementations [9]. As Wheeler and Spencer (1940) noted, nearly all body-section radiography apparatus up to that date were based on principles first enunciated by Bocage in 1921 [10].

International collaboration accelerated progress through the mid-20th century. By 1959, Wilk had developed axial transverse tomography for chest imaging—horizontal "slices" representing a conceptual leap toward modern CT geometry [3]. Researchers also explored inversions of the classical Radon transform on Euclidean spaces [2]. The culmination arrived in the 1970s when Godfrey Hounsfield built the first commercial CT scanner, directly applying Radon's principles, and shared the 1979 Nobel Prize with Allan Cormack [4,5]. Collectively, this international scholarship demonstrates that tomography evolved through continuous exchange across Europe and North America—involving mathematicians, physicists, radiologists, and engineers who independently converged on solving non-invasive, layer-by-layer human examination [1–11].

The core study acknowledges the contributions of Russian scientists. The relevance of the chosen topic stems from the fact that reconstructive (non-destructive) tomography, as a non-invasive research method, holds exceptional importance in contemporary medical practice. New historical findings help uncover previously little-known aspects of tomography's history and reveal the names of scientists who made substantial contributions to the development of tomography theory and the design of original X-ray tomographs.

The theory and practice of tomography have undergone a long developmental path, the main milestones of which are outlined in modern historical medical literature [8–17]. However, the names of some scientists, their views, and practical contributions to tomography have not been subjected to in-depth scientific analysis, and their impact has not been adequately recognised.

2. Objectives of the study

Among the key events in the history of medicine—and, in particular, the history of tomography—a special place is occupied by the emergence of new research methods in the 19th century, notably the method known as "ice anatomy". The first experiments involving the freezing of cadavers for anatomical studies were conducted by the Russian anatomist and surgeon I. Buyalsky, who laid the foundations of comparative and topographic anatomy. In preparing his scientific works, Nikolai Pirogov also employed the "ice anatomy" method, validating his findings on extensive pathoanatomical material. For his work on the pathological anatomy of Asiatic cholera (1849–1850), he performed autopsies on 900 frozen cadavers using the "ice anatomy" technique [18].

Developing the method further, Professor N. Pirogov pioneered the total slicing of frozen cadavers into thin sections (5–10 mm) in three planes—frontal, horizontal, and sagittal—in 1851. This research method enabled him to study the topography of human organs and body parts. In 1853, the results were published in the seminal work *Illustrated Topographic Anatomy of Sections Made in Three Dimensions Through a Frozen Human Body* [19]. Published in Latin, Pirogov's work marked the beginning

of topographic anatomy. The three-dimensional images in the atlas anticipated the future emergence of X-ray tomography-based research methods. Professors Ilya Buyalsky and Nikolai Pirogov of the St. Petersburg Medico-Surgical Academy stood at the origins of the layer-by-layer examination method for human organs and body parts—a method that underlies modern tomography [20-24].

In scientific works devoted to the history of tomography, it is rightly noted that among the numerous discoveries influencing the development of research methods, a special place belongs to the discovery of X-rays—later named "Roentgen" radiation. This breakthrough enabled scientists to launch intensive theoretical and practical work in the field of tomography [24-26]. Studies of the properties of integral equation families, conducted by mathematicians I. Fredholm and N. Abel in the 19th century, later became the mathematical foundation of tomography. The mathematical algorithms required for tomography were developed in 1917 by Johann Radon and later (in 1963) validated by A. Cormack [25]. In 1934, the German company Sanitas became the first in the world to launch serial production of linear tomographs.

3. Applications' challenges for some types of Tomographs

X-ray tomography began to be widely applied in practice, primarily for refined diagnosis of lung diseases—in particular, determining the location of cavities and tumours. From the late 1940s, the method was also extensively used in diagnosing diseases of the paranasal sinuses [25].

An analysis of periodical publications from the first half of the 20th century indicates that Vissarion Feoktistov, an engineer-designer and researcher at the Department of Radiology of the S. Kirov Military Medical Academy of the Red Army, scientifically substantiated Radon's algorithms as early as autumn 1935. He presented to the scientific community two tomographs of his own design, along with medical images produced using these devices. In 1936, Feoktistov's original tomograph designs were showcased at an exhibition of X-ray equipment during the All-Union X-ray Conference held in Leningrad.

In the course of theoretical and practical work, it became clear that neither abroad nor in Russia was there a coherent theory of single-layer imaging that would cover all possible cases of tomography. In the early 20th century, the focus was mainly on describing various tomograph designs. No comparative analyses or thorough mathematical justifications were provided. Until 1938, publications on this topic were not so much scientific articles as review and popular-science materials.

One of the first research works revealing the theoretical foundations of tomography was V. Feoktistov's article "Theory of Tomography" [20]. This work aimed to provide a complete theory of tomography and, on this basis, establish the principal types of possible tomograph designs. The author's exposition was built upon the principles of elementary mathematics. Feoktistov presented an equation that, in his view, constituted the foundation of the entire theory of tomography.

Feoktistov mathematically substantiated and visually demonstrated the possible types of tomographs. He noted that the direction of movement of the tomograph's moving parts could vary—a straight line, a circular arc, or a more complex curve (such as a circle or spiral). Based on these classifications, he substantiated the possibility of manufacturing 18 fundamentally feasible types of tomographs. The practical feasibility depended on the ease of structural design and convenience of imaging. Feoktistov provided mathematical calculations of the degree of "blurring" (smearing) in X-ray tomographic images and pointed out the dependence of shadow blurring on the travel distance of the X-ray tube. His ideas significantly expanded the knowledge base in the field.

3.1. Applications' challenges for the first type of Tomographs

The first type represented Feoktistov's original design, involving changing the absolute values of heights and edges while preserving the constancy of their ratios. The "smearing" of unwanted shadows occurs through smooth diffusion in all directions. An inverter mechanism maintains constant ratios of heights and edges and parallel alignment of the cassette and imaging layer. Design challenges prevent practical implementation of this type, though the smearing pattern can be advantageous in certain cases. Apart from Feoktistov's own laboratory model, this type has never been constructed or introduced into clinical practice.

3.2. Applications' challenges for the second type of Tomographs

The second type maintained constant absolute values of heights. Smearing was performed along a straight line or a curve (circle, spiral). In linear smearing, the object remains stationary while the X-ray tube and film cassette move in opposite directions along parallel rails. Synchronism was achieved by transforming one large edge into a rod with a centre of rotation, which moved the cassette and tube in opposite directions and continuously rotated the tube so that the central ray was always directed at the cassette center. This principle was used in the Siemens tomographic stand and a similar stand developed by Professor Gasul. Among curvilinear motions, circular movement deserves particular attention, with the rod moving tube and cassette while keeping their edges parallel (Fig. 1). A modification with a stationary tube and movement of object and screen was structurally easier to implement for circular motion. In circular motion, the tube remains at a constant distance from the centre of the object's "cut" and the cassette centre throughout rotation, so only rotation of object and cassette is needed. According to Feoktistov, this modification deserves serious consideration.



Fig. 1. The first computed tomograph (1972). Source: <https://www.medmuseum.siemens-healthineers.com/en/stories-from-the-museum/history-of-ct>

3.3. Applications' challenges for the third and combined types of Tomographs

The third type featured constancy of one pair of edges in absolute magnitude. Structural implementation encountered no difficulties, as the rod length remained unchanged. The film cassette remained parallel to itself during movements via a special suspension. A tomograph of this type with linear movement was constructed by the Sanitas company. The constant distance between object and X-ray tube made it easy to implement a modification with a stationary X-ray tube.

The combined type of tomograph was an original design by Vissarion Feoktistov. It allowed for: a) linear motion of the third type in all directions, adjustable as desired—not limited to a single direction, as with the Sanitas tomograph; b) all other motions possible in the third type; c) rotational motions of the second type, with an adjustable radius. The combined type employed a gimbal mounting system for the axes and achieved complete balancing of all moving parts. The central ray was directed at the centre of the cassette during all movements. Feoktistov's tomograph (Fig. 2) was equipped with an automatically operating marker to record slice heights and a special cassette for producing tomograms of inclined, curved, double, and triple "slices". Images were acquired with the patient supine.



Fig. 2. Feoktistov's tomograph

Source: <https://prezentacii.org/prezentacii/prezentacii-raznie/152778-metody-issledovaniya-golosovogo-apparata.html>

A critical assessment of the tomograph proposed by V. Dubinin was provided by Vissarion Feoktistov, commissioned by the editorial board of the Bulletin of Radiography and Radiology. The debate focused on whether Dubinin's apparatus could image a specific layer by measuring pendulum axis oscillations. Feoktistov said this was unproven. Theoretical investigation demonstrated that acquiring a layer-by-layer X-ray representation through Dubinin's stand configuration was not viable. The fundamental requirement for successful layer-by-layer imaging is that shadows of elements from one specific "layer" must remain stationary on the film throughout the motion. Feoktistov clearly demonstrated his viewpoint using illustrative diagrams [20;27].

An original tomograph corresponding to the second type according to Feoktistov's classification was developed in the 1930s by scientists at the Leningrad

State Roentgenological, Radiological and Cancer Institute: Sergei Yanshek, in collaboration with engineer N. Chablin, under the supervision of department head engineer A. Tkhorzhevsky and institute director Professor M. Nemenov. The theoretical foundation was presented by S. Yanshek in the Bulletin of Radiology and Radiology, titled "A Tomograph of Original Design". The operating principle: the X-ray tube remained stationary while the object and film rotated around their own axes (axes perpendicular to the plane and parallel). Their rotational movements were strictly coordinated by a connecting rod hingedly linked to the film frame and object frame (Fig. 3). Under this motion, a tomographic image of the object's plane was obtained—parallel to the film plane and passing through the object's axis of rotation.



Fig. 3. Tomograph of original design

Source: https://ru.ifixit.com/News/109137/a-guide-to-reading-ct-scans-part-1-what-is-ct?utm_medium=organic&utm_source=yandexsmartcamera

The structural design was remarkably simple (Fig. 4), naturally balanced, required no counterweights, and was lightweight. Forces required were negligible, and the drive mechanism was simple. Due to the stationary X-ray beam, X-ray protection conditions were elementary. Tomographs that entered practice in the early 20th century (Sanitas, Siemens, Comp. GendeRadiol, Maison, Massiot) had drawbacks: bulkiness due to wide movement of tube and cassette, trailing high-voltage cables, high cost. Yanshek's tomograph was largely free from these drawbacks. The stationary tube eliminated complex high-voltage supply. As for image quality, the nature of shadow smearing was essential—choosing magnitude, shape, and direction. Yanshek's design addressed these requirements. The absence of vertical or rotational movements of the screen allowed direct observation of shadows. Use of this tomograph in pulmonary diagnostics over several months revealed the need to

develop imaging techniques and leverage the tomograph's capabilities. Yanshek's design was primarily intended for pulmonary diagnostics—an area of high need—with potential for other fields [28]. Coinciding with the publication of Yanshek's 1938 article, a French journal published a photograph of a similar tomograph but without design specifications or practical results.

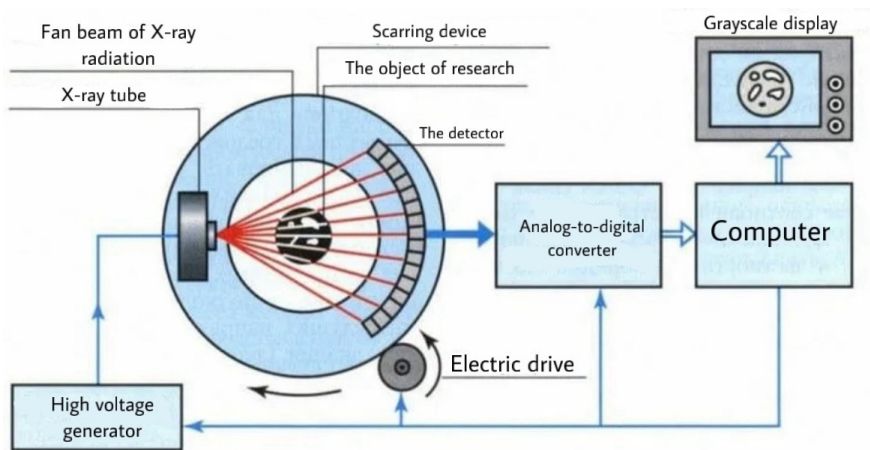


Fig. 4. Design of the tomograph built according to S. Yanshek's scheme

Source: https://medicray.ru/blog/kak-rabotaet-kt-omograf/?utm_medium=organic&utm_source=yandex_smartcamera

X-ray tomography was successfully used in medicine for more than half a century. However, as more advanced fluoroscopic equipment emerged, its use nearly ceased by the late 1970s. It was replaced by CT, MRI, and PET [29].

At the present time, the field is undergoing yet another revolution, driven by three transformative dimensions. Firstly, photon-counting CT (PCCT) achieves resolution between 0.2 and 0.4 mm with a radiation dose reduction of 30–40%, transforming cardiac, oncological and paediatric diagnostics. Mayo Clinic researchers observe that PCCT signifies a "milestone" redefining clinical imaging standards. Secondly, AI has become the core software engine for low-dose reconstruction. The Noise-inspired Diffusion Model (NEED) demonstrates excellent generalisation capabilities, outperforming state-of-the-art methods in reconstruction fidelity and structural preservation. Zero-Shot Self-Similarity-Steered Denoiser operates without paired training data. Thirdly, multimodal X-ray imaging enables acquisition of attenuation, differential phase, and dark-field signals using phase contrast, revealing soft tissue and microstructures, transforming lung disease diagnosis and breast cancer screening with minimal hardware modification.

The study reveals clear continuity, linking foundational historical work with today's transformative technologies. Historical analysis systematises previously under-researched data: chronology, contributions of Buyalsky, Pirogov, Feoktistov, and early engineering achievements (Feoktistov, Yanshek, Chablin, Gasul). Feoktistov's mathematical algorithms (1938) are highlighted as a methodological foundation. This continuity demonstrates direct technological lineage from 19th-century layer-by-layer examination to breakthrough 20th-century designs. This foundation has now converged with cutting-edge innovations driving a new revolution. PCCT achieves 0.2–0.4 mm resolution and reduces radiation dose by 30–40%. AI now serves as the core engine for low-dose reconstruction. Multimodal X-ray imaging—pioneered by University College London—enables acquisition of attenuation,

differential phase, and dark-field signals. The convergence of PCCT, AI-driven reconstruction, and phase-contrast techniques marks a new era, transforming tomography into a spectral, intelligent, and multimodal platform. The study proposes a reproducible analytical framework (chronological systematisation, personalisation of scientific contributions, demonstration of technological continuity, validation of practical relevance) applicable to other fields.

Key findings of *Applications’ challenges for some types of Tomographs*: continuity of scientific achievements from 19th–20th century works to modern technologies (PCCT, AI, phase contrast); systematized historical data (chronology, contributions, technical solutions); and a reproducible analytical framework for assessing scientific progress.

4. Contribution to the epistemic international medical community, global standartisation, and clinical impact

The Russian scientific legacy fundamentally shaped the epistemic infrastructure of the entire international medical tomography community. The journey from Feoktistov's first prototype to today's global standards like DICOM was paved by this epistemic community. Their "common policy enterprise" focused on quality and safety, enabling high-quality, multi-specialty imaging. Feoktistov created the first operational X-ray tomograph (1934–35) and formalised the "metric properties" of images. Yanshek patented a tomographic apparatus in 1937 and later designed a multi-tube system minimising motion blur. Dubinin contributed essential experimental validation in clinical settings. Together, they transformed abstract mathematics into reproducible, clinically relevant technology, solidifying shared causal beliefs (controlled motion solves superimposition), validity criteria (quantitative metrics), and a common policy enterprise (standardisation of image quality and safety). This universal framework enabled later development of DICOM and low-dose protocols, uniting specialists across political divides (Fig. 5). The core rests on three pillars: shared causal beliefs (controlled source-detector motion solves superimposition; image quality rooted in physical principles first demonstrated by pioneers); shared validity criteria (objective, reproducible metrics such as MTF and NPS, traceable to Feoktistov's "metric properties"); and a common policy enterprise (standardising image quality and safety, harmonising protocols, developing DICOM). Clinical impact includes teleradiology, artificial intelligence, multi-centre trials, and higher quality diagnosis worldwide.

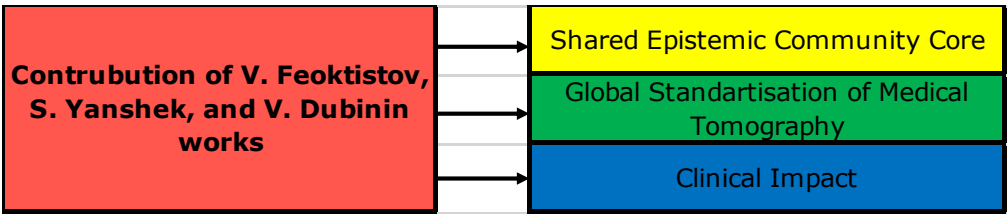


Fig.5. Contribution to the international Epistemic Community. Authors' elaboration.

5. Conclusion

In the nineteenth century, scientists first attempted to examine the human body layer-by-layer. Buyalsky and Pirogov of the St. Petersburg Medico-Surgical Academy developed fundamental methods for tomography. In the early 20th century, tomographs developed by Feoktistov, Yanshek, Chablin and Gasul were revolutionary. Since then, mechanical principles have evolved significantly, driven by global contributions from Bocage, Kieffer, Ziedses des Plantes and others. Russian and international developments laid the foundation for tomography as an effective, non-invasive method of layer-by-layer human examination. These achievements inspired further scientific inquiries and technical solutions. The convergence of PCCT, AI-driven reconstruction and phase-contrast techniques marks a new era. Tomography is evolving from a binary attenuation-based tool into a spectral, intelligent, multimodal platform—fulfilling the vision that pioneers like Pirogov, Buyalsky, Feoktistov, Bocage, and Radon first imagined over a century ago.

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