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COMPARATIVE PERFORMANCE OF CONVENTIONAL RADIOGRAPHY AND DIGITAL RADIOLOGICAL PROCESSING IN THE EXAMINATION OF THE PARANASAL SINUSES

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Abstract. This article compares the diagnostic performance of conventional radiography of the paranasal sinuses with digital radiological processing of the same images, using computed tomography as the reference method, in 174 patients. The main group comprised 106 patients with rhinosinusitis, the control group 32 healthy volunteers, and the comparison group 36 archival cases with radiography and CT but without digital processing. For the original and the processed images, in comparison with CT, we calculated sensitivity, specificity, positive and negative predictive values, the area under the ROC curve (AUC), and the agreement coefficient.

Keywords: paranasal sinuses, rhinosinusitis, conventional radiography, digital radiological processing, image processing, computed tomography, diagnostic performance.

Background

Diseases of the paranasal sinuses occupy a significant place in the structure of ENT pathology and remain a pressing medical and social problem. Chronic rhinosinusitis (CRS) is one of the most common chronic diseases in the world, affecting all age groups. Its frequency is 12.3 % in the USA, 10.9 % in Europe, and 13 % in China. According to current reviews and guidelines (EPOS 2020 and others), the prevalence of CRS in the population ranges roughly between 5 and 12 %, while updated meta-analyses estimate the global pooled prevalence at about 8.7 % (95 % CI 6.7–11.3) [1]. CRS is also a disease that markedly reduces patients' quality of life. It has been shown that CRS has a greater impact on social functioning than coronary heart disease or chronic heart failure [3, 4].

Conventional radiography in rhinosinusitis remains an accessible method for primary examination, but its diagnostic value is limited: there is low sensitivity to early or localized changes, an overlap effect of anatomical structures, and dependence of interpretation on the physician's experience. According to foreign authors, the routine use of radiography in uncomplicated forms of acute sinusitis is not recommended because of its low diagnostic value and the high likelihood of diagnostic errors. Comparative studies show that, relative to CT, plain radiography has substantially lower sensitivity (for example, 57–80 % depending on the sinus; especially low for the frontal, ethmoid, and sphenoid sinuses), whereas specificity remains relatively high [5, 6].

In this regard, CT is considered a more informative method for assessing the extent and nature of pathological changes, especially in frontal sinusitis and ethmoiditis; the relevant guidelines (ACR Appropriateness Criteria) emphasize the preference for CT/MRI in certain clinical scenarios and the lack of need for routine imaging in uncomplicated acute rhinosinusitis [7–9]. The development of digital technologies has enhanced the diagnostic potential of radiography: digital radiological processing (noise reduction, edge/contrast enhancement, window/level optimization, reconstructions) and the ideologically similar digital tomosynthesis technique demonstrate improved visualization and increased accuracy in the assessment of the paranasal sinuses compared with classic film techniques. It

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has been shown that the digital tomosynthesis projection of the paranasal sinuses provides high diagnostic accuracy and inter-observer agreement, approaching CT in key metrics [10–12].

In addition, meta-analyses indicate that, overall, radiography demonstrates moderate values (sensitivity ~73 %, specificity ~80 %), while CT remains the reference standard for assessing anatomy and disease extent. This underscores the clinical relevance of comparing conventional radiography and digital radiological processing in terms of diagnostic value and reduction of the proportion of false-positive/false-negative conclusions [13, 14]. Current trends in radiological diagnosis of the paranasal sinuses are linked to the development of digital radiological processing and the integration of artificial-intelligence methods. Digital processing of radiological images makes it possible to substantially increase the informativeness of conventional radiography through the use of algorithms for noise suppression, edge and contrast enhancement, and image reconstruction in various planes. This provides clearer visualization of the mucous membrane and detection of fluid levels and polypoid formations, which helps reduce the number of false-positive and false-negative conclusions.

Additionally, the use of machine-learning and deep-learning algorithms creates the prerequisites for automating image analysis. A number of studies have shown that neural network models are able not only to segment anatomical structures and pathological changes with high accuracy but also to form preliminary diagnostic conclusions comparable to the results of experienced radiologists. Such approaches make it possible to standardize the interpretation process, minimize the influence of the human factor, and increase the reproducibility of results. Thus, digital radiological processing and artificial-intelligence algorithms are becoming key tools for increasing the diagnostic value of paranasal sinus radiography and represent a promising direction in the development of modern ENT radiology. On this basis, the present work aims to compare the performance (sensitivity, specificity, AUC) of conventional radiography and digital processing in the examination of the paranasal sinuses, with analysis of the proportion of diagnostic errors against the “gold standard” (CT) as a reference.

The aim of the study was to assess the diagnostic performance of conventional radiography and digital radiological processing in the examination of the paranasal sinuses, with analysis of the frequency of false-positive and false-negative results relative to computed tomography data as the “gold standard.”

Materials and methods

The study included 174 people, divided into three groups. The main group comprised 106 patients with clinical signs of rhinosinusitis. Among them, maxillary sinusitis was diagnosed in 71 patients (67.7 %), frontal sinusitis in 22 patients (20.1 %), and combined forms of pathology (involvement of several locations) in 13 patients (12.2 %). The control group included 32 healthy volunteers with no clinical or radiological signs of paranasal sinus pathology, which made it possible to assess the specificity of the methods studied. The comparison group consisted of 36 patients whose archival data contained conventional radiographs and CT of the paranasal sinuses but no digital radiological processing. Thus, the total sample size provided sufficient statistical power to compare the diagnostic informativeness of conventional radiography and digital radiological processing relative to CT data as the “gold standard.”

Table 1. Distribution of the examined subjects by group and nosological form

Group	Number	Structure within the group	%

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Group	Number	Structure within the group	%
Main group (patients with rhinosinusitis)	106	Maxillary sinusitis — 71 Frontal sinusitis — 22 Combined forms — 13	67.7 % 20.1 % 12.2 %
Control group (healthy volunteers)	32	No paranasal sinus pathology	—
Comparison group (archival data)	36	Radiography + CT (no digital processing)	—
Total	**174**		

All patients underwent: conventional radiography (two projections), digital radiological processing of the same images, and computed tomography (CT) of the paranasal sinuses, used as the "gold standard." The comparative indicators were: the sensitivity and specificity of conventional radiography; the sensitivity and specificity of digital radiological processing; the number of false-positive and false-negative conclusions; positive and negative predictive values (PPV, NPV); ROC analysis and determination of the area under the curve (AUC); and comparison of all methods with the CT results as the reference standard.

The study comprised analysis of the diagnostic informativeness, reproducibility, and accuracy of conventional radiography and digital radiological processing, using CT as the control method.

Results

Analysis of the diagnostic performance of conventional radiography, digital radiological processing, and their comparison with computed tomography (CT) data (Fig. 1) as the "gold standard" revealed substantial differences in the informativeness of the methods, the number of diagnostic errors, and the reproducibility of results.

In the main group, which included patients with various forms of rhinosinusitis (maxillary sinusitis — 67.7 %; frontal sinusitis — 20.1 %; combined forms — 12.2 %), each patient underwent three types of examination: conventional radiography, digital radiological processing, and CT of the paranasal sinuses.

Fig. 1. Methods of conventional radiography (a) and computed tomography (b) in left-sided maxillary sinusitis

On comparison of the results of conventional radiography with CT, the diagnostic informativeness of the method was established (Fig. 2).

The main causes of diagnostic errors were: insufficient visualization of the posterior parts of the ethmoid labyrinth and the sphenoid sinus, the overlap effect of structures, and limited image resolution.

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After digital processing of the same images, a statistically significant improvement in the parameters was observed (Fig. 3):

Fig. 3. Digital processing of conventional radiography and CT images. Radiograph (top row): after digital processing the image became more contrasted, the borders of the bones and sinuses are seen more clearly, and opacities in the maxillary sinus region stand out better. CT (bottom row): the detail of soft tissues and bony structures is improved and local contrast is increased — this facilitates visualization of the mucous membrane and fluid levels.

The application of digital processing (Fig. 4) made it possible to clearly visualize mucosal thickening, fluid levels, and polypoid formations, and to eliminate noise artifacts previously interpreted as pathological shadows.

In the comparison group (n = 36), only archival radiographs and CT were analyzed. The data obtained demonstrated (Fig. 5): a sensitivity of conventional radiography of 67.7 %, specificity 74.2 %, false-negative conclusions 22.2 %, and false-positive conclusions 16.7 %.

Fig. 4. Pseudocolor (heat-map) processing. Radiograph (left): contrast transitions are enhanced, bones are highlighted in brighter shades, and soft tissues are marked by dark zones. This facilitates visual perception of the sinus borders. CT (right): bones and dense structures are “overexposed” in yellow-orange, while less dense tissues and sinuses are highlighted in violet-blue.

The absence of digital processing was accompanied by a high proportion of diagnostic errors, especially in sphenoiditis and multisinusitis. These results confirmed the limited value of film radiography without subsequent digital correction.

Fig. 5. Key diagnostic indicators by method

Fig. 6. ROC analysis of the diagnostic methods

The graph shows the ROC curves for the two methods (Fig. 6):

– Conventional radiography (dashed line) with AUC = 0.74

– Digital radiological processing (solid line) with AUC = 0.87

The higher the curve and the area beneath it, the higher the diagnostic accuracy of the method. As can be seen, digital processing significantly surpasses conventional radiography in sensitivity and specificity (Fig. 7).

Fig. 7. Diagnostic sensitivity by type of rhinosinusitis

In the healthy volunteers (n = 32), the radiological examination also revealed differences between the methods. The specificity of conventional radiography was 75.0 %, with false-positive conclusions obtained in 8 patients (25 %). After digital processing, false-positive findings were detected in only 2 people (6.2 %), which indicates the high ability of digital processing to eliminate subjective interpretation errors (Fig. 8).

Fig. 8. Comparison of the clinical significance of the results — how reliably a positive/negative result can be regarded

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The study results convincingly demonstrated that digital radiological processing provides a significant increase in the accuracy, sensitivity, and specificity of the radiological method in the diagnosis of inflammatory diseases of the paranasal sinuses (Table 1). Incorporating this approach into clinical practice makes it possible not only to increase the reliability of diagnosis but also to reduce the proportion of false-positive and false-negative conclusions, especially in cases of atypical course and multisinusitis (Fig. 9).

Fig. 9. Diagnostic errors by method

Discussion

The results obtained confirm that conventional radiography, despite its accessibility and widespread use in clinical practice, has limited diagnostic value in the assessment of inflammatory diseases of the paranasal sinuses. The low sensitivity (69.8 %) and specificity (75.0 %) of radiography are related primarily to the features of the method: the overlap effect of anatomical structures, reduced informativeness in frontal sinusitis and sphenoiditis, and a limited ability to detect minimal mucosal changes. This is also confirmed by the data of the comparison group, where the use of conventional radiography alone led to a high number of diagnostic errors (false-positive — 16.7 %, false-negative — 22.2 %).

Incorporating digital radiological processing into the patient examination algorithm substantially increased the diagnostic accuracy of the method. Image processing using noise-suppression, edge-enhancement, and contrast-optimization technologies made it possible to improve the visualization of fluid levels, mucosal hyperplasia, and polypoid growths. The sensitivity of the method rose to 83.0 %, specificity to 87.5 %, while the PPV and NPV reached 87.2 % and 83.3 %, respectively. Particularly important was the reduction in the proportion of false-positive conclusions in the control group from 25 % with conventional radiography to 6.2 % with digital processing, which demonstrates a significant reduction of the subjective factor in image interpretation. The ROC-analysis results also confirm the advantage of the digital method: the area under the curve (AUC) was 0.87 versus 0.74 for conventional radiography, which reflects higher diagnostic informativeness. The reproducibility analysis showed an increase in the agreement coefficient κ from 0.61 to 0.72 with the use of digital processing, which indicates a reduction in inter-observer variability and an increase in the objectivity of interpretation. When comparing different nosological forms, it was noted that digital processing increases sensitivity most of all in frontal sinusitis and combined forms of pathology, where conventional radiography more often underestimated the extent of the process. This is related to the more pronounced overlap effect of structures in the region of the frontal and ethmoid sinuses with the standard method.

At the same time, even digital radiography is inferior in accuracy and reproducibility to computed tomography. CT remains the “gold standard” for diagnosing paranasal sinus diseases, providing maximum sensitivity and specificity as well as the ability to quantitatively assess pathological changes and their extent. However, its high cost, limited availability, and radiation exposure make it impossible to use CT as a primary screening method. In this regard, digital radiography is regarded as the optimal compromise option, allowing the diagnostic informativeness of the conventional method to be substantially increased without additional expenditure on costly equipment. Thus, discussion of the data obtained shows that digital radiological processing is a promising direction in the development of radiological diagnosis in otorhinolaryngology. It makes it possible to minimize diagnostic errors, increase the reproducibility of results, and bring the

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informativeness of radiography closer to CT data, while remaining an accessible and economically feasible method.

Conclusion

The study conducted demonstrated that conventional radiography has limited diagnostic value in detecting inflammatory diseases of the paranasal sinuses, especially in cases of frontal sinusitis, sphenoiditis, and combined forms of pathology. Its low sensitivity and specificity, as well as the high percentage of false-positive and false-negative conclusions, limit its use as a reliable diagnostic tool. Incorporating digital radiological processing into the patient examination algorithm substantially increases the informativeness of the method. Processing of radiographs makes it possible to significantly improve the visualization of the mucous membrane, fluid levels, and polypoid changes, which leads to an increase in sensitivity to 83.0 %, specificity to 87.5 %, and an increase in the reproducibility of conclusions ($\kappa = 0.72$). Thus, digital radiography provides higher diagnostic accuracy compared with the conventional method and can be regarded as an optimal intermediate link between radiography and computed tomography. Computed tomography remains the "gold standard" for diagnosing paranasal sinus diseases owing to its maximum sensitivity, specificity, and capabilities for quantitative assessment of pathological changes. However, its high cost, limited availability, and radiation exposure prevent its use as a primary screening method. The results obtained confirm that digital radiological processing can substantially increase the performance of conventional radiography and can be recommended for wide implementation in the practice of otorhinolaryngology departments as an accessible and clinically significant diagnostic tool.

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