Frontiers in Health Informatics
ISSN-Online: 2676-7104
www.healthinformaticsjournal.com
2024; Vol 13: Issue 6
Open Access

Review Of The Use Of Tomosynthesis For The Diagnosis Of Injuries And Diseases Of The Musculoskeletal System

Kenjayev Sherzod Ravshan o'g'li
e-mail: sherzodbek.4512@gmail.com
Orcid: 0009-0006-7665-4723
Fergana Medical Institute of Public Health

Qoraboyev Jasurbek Mavlonjon o'g'li
e-mail: jasurbekqoraboyev94@gmail.com
Orcid: 0009-0001-2721-5402
Fergana Medical Institute of Public Health

Cite this paper as: Kenjayev Sherzod Ravshan o'g'li,Qoraboyev Jasurbek Mavlonjon o'g'li (2024) Review Of The Use Of Tomosynthesis For The Diagnosis Of Injuries And Diseases Of The Musculoskeletal System*Frontiers in Health Informatics, 13* (6), 742-748

Abstract. Digital tomosynthesis is a radiological examination method that occupies an intermediate position between radiography and computed tomography (CT). Its undeniable advantages include high image quality, the possibility of post-processing of images (with a slice thickness of up to 1 mm), minimization of projection overlaps and low dose load (in comparison with CT). The tomosynthesis technique is most widely used in diagnostics of diseases of the mammary gland, lungs (including tuberculosis), musculoskeletal system, and oral cavity. However, the professional community still lacks a coordinated position on the advisability of using tomosynthesis to diagnose injuries and damage to the musculoskeletal system. The main goal of this work was to systematize data on the advisability and effectiveness of using tomosynthesis in diagnostics of injuries and diseases of the musculoskeletal system.

Keywords: tomosynthesis, musculoskeletal system, trauma, joint, spine.

INTRODUCTION

Digital tomosynthesis (from the Greek tomos – section, synthesis – placing together) is a radiological examination method, which, in terms of diagnostic capabilities, occupies an intermediate position between radiography and computed tomography (CT). Its undeniable advantages include high image quality, the possibility of post-processing image processing (with a slice thickness of up to 1 mm), minimization of projection overlaps and low dose load (in comparison with CT) [1, 2]. Being a reconstructive visualization method, tomosynthesis is widely used to diagnose diseases of the mammary gland, lungs (including tuberculosis), musculoskeletal system, and oral cavity. The effectiveness and significance of the described method have been best studied in the aspect of diagnosing non-palpable formations and other pathologies of the mammary glands.

Tomosynthesis is used to monitor reparative processes in fractures of long bones of the limbs, as well as the olecranon, allowing to identify both delayed union and severe complications (for example, repeated fractures - refractures) in the postoperative period [3, 4, 5, 6]. The possibility of performing digital tomosynthesis with contrast for diagnosing femoroacetabular impingement syndrome (impingement) has been demonstrated - clinically significant damage to the edge of the acetabulum and pathological changes in the cartilage were detected [7]. If damage to the scaphoid bone is suspected, tomosynthesis allows not only to diagnose the condition, but also to exclude the use of other modalities [8]. Tomosynthesis is used for early diagnosis of sacroileitis in adults [2], various injuries and diseases of bones and joints in children [3]. It has been preliminarily shown that in traumatic spinal injuries the sensitivity of tomosynthesis is 54.0%, specificity is 80.0% (for radiography 25.0% and 67.0%, respectively); the resolution of tomosynthesis is close to computed tomography (CT), and the patient radiation dose is lower than with CT (1.2 mSv and 12 mSv, respectively) [2]. The capabilities of the method for identifying subtle injuries and minimizing noise from metal implants, which *complicate diagnostics using computed tomography, have been demonstrated [3]. At the same time, there is data on the limited capabilities of the method (for example, for identifying erosions in gout [4]). There is no agreed position in the professional community on the advisability of using tomosynthesis for diagnosing injuries and damage to the musculoskeletal system. In this regard, we believe it is necessary to systematize the accumulated experience in a global perspective and determine the paths for further development of the method.*

MATERIALS AND METHODS

The study design is a systematic review conducted in accordance with the methodology of "The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions" [5]. To find relevant articles in Russian, search queries were used that included the terms and phrases: "tomosynthesis", "joint", "spine", "bone tissue", "bone", "arthritis".

Publication inclusion criteria:

– compliance with the topic of the systematic review,

– original research (phantom, diagnostic, clinical),

– publication in a peer-reviewed journal,

– objective data on the methodology and effectiveness of tomosynthesis for diagnosing injuries and diseases of the musculoskeletal system are provided.

Then the following data were selected from each publication:

– author's name, year of publication, country;

– objective;

– study design;

– testing of statistical hypothesis;

– nosology, localization;

– description of method, method of application, diagnostic value;

– result of effectiveness assessment;

– general results.

RESULTS AND DISCUSSION

In the process of analyzing publications, we have formed 4 leading areas of tomosynthesis use for diagnostics of injuries and diseases of the musculoskeletal system:

1) rheumatoid arthritis (hand, foot);

2) specific and non-specific lesions and injuries of the spine;

3) non-specific lesions and injuries of the joints;

4) barely noticeable fractures and dislocations.

1. Rheumatoid arthritis (hand, foot)

Digital tomosynthesis is most widely used in diagnostics and monitoring of the progression of rheumatoid arthritis. Several studies have conducted a comparative study of the diagnostic value of tomosynthesis and radiography for detecting erosions, with computed tomography (CT) or magnetic resonance imaging (MRI) used as the "gold" standard. In all studies, image analysis was performed using the Sharp index modified by van der Heijde by two or three independent experts. The summarized data are presented in Table 1. We would also like to point out that the positive predictive value of a positive result for radiography is 77.0%, for tomosynthesis – 76.0%; and a negative result is 71.0 and 80.0%, respectively [6]. In all studies, the sensitivity, specificity, and accuracy values for radiography are significantly lower than for tomosynthesis and CT or MRI. False positive results obtained with tomosynthesis are due to the fact that the subchondral bone plate is too thin in thin sections, practically invisible, which prompts the radiologist to indicate the presence of erosion (especially when examining the interphalangeal and metacarpophalangeal joints). The false-positive rate for radiography and tomosynthesis is identical [6, 7]. False-negative results are mainly associated with the interpretation of metacarpal bone lesions [8]. Thus, the diagnostic value of digital tomosynthesis in rheumatoid arthritis is higher than standard radiography and is almost equivalent to CT and MRI.

The average Sharp/van der Heide index is significantly lower for radiography (compared to tomosynthesis or the "gold" standard) [6, 7]; it is also significantly lower for tomosynthesis compared to CT [7]. In terms of the number of erosions detected in rheumatoid arthritis, tomosynthesis and CT are comparable, while they significantly exceed standard radiography of the hands and feet. The average total dose per patient is minimal when using radiography and maximal for CT. The use of tomosynthesis slightly (statistically insignificantly) increases the radiation dose, but significantly improves the quality of diagnostics, approaching the significance of CT and MRI. The agreement of diagnostic decisions of radiologists regarding the presence of erosions in all joints is highest when using tomosynthesis and MRI (Cohen's kappa coefficient is 0.65–1.00 and 0.680–1.00, respectively), while it is significantly lower when using radiography (Cohen's kappa coefficient is 0.22–0.56). The advantage of MRI is the ability to detect synovitis and edema, but the use of this modality for screening and monitoring in rheumatoid arthritis is extremely difficult due to its cost and technical complexity [18]. Comparative chronometry of the studies was not carried out. The researchers only indicate that subjectively the time costs for interpretation are almost identical for tomosynthesis and CT or MRI, while radiography takes less time [16, 18]. There is also evidence that the qualification of the physician interpreting the tomosynthesis results does not affect the detection of cysts (in contrast to the detection of osteophytes) [3]. It should be noted that back in 2003, a phantom study showed that the width of the joint space can be reliably measured on images of the hand obtained by tomosynthesis. Phantom studies on image processing - selection of filters and reconstruction - are currently ongoing. Despite the promise of these technologies for assessing the degree of joint damage in arthritis, they do not find clinical application [4].

Table 1

Summary data on the diagnostic accuracy of tomosynthesis and radiography of the hands and feet in rheumatoid arthritis

	Radiography	Tomosynthesis	Radiography	Tomosynthesis	Radiography	Tomosynthesis
Author	Simoni P. et al., 2015		Canella C. et al., 2011		Aoki T. et al., 2014	
Number of patients	18		30		20	
Sensitivity, %	66,0	80,0	53,9	77,6	68,1	94,8
Specificity, %	81,0	75,0	92,0	89,9	97,5	97,8
Accuracy, %	74,0	78,0	70,9	83,1	86,7	96,7
Average Sharp/van der Heide index	16,4 ± 18,0	18,8 ± 16,8	86,7	17,4 ± 16,2	–	–
Dose, mGy	0,42	0,56	0,13	0,25	0,070	0,185

Thus, tomosynthesis significantly improves the detection of erosions in rheumatoid arthritis. At present, it is regarded as a promising technology for monitoring the progression of rheumatoid arthritis and the effectiveness of its drug therapy [7]. However, its reliability should be further studied in large clinical trials. The diagnostic capabilities of tomosynthesis and ultrasound examination of small joints of the hands and feet should also be compared [6, 8]. One study emphasizes that until such clinical data are obtained, the use of radiography may remain preferable [6]. A certain argument confirming the advisability of further research in this direction is that with hand tomosynthesis, a significant dose reduction is possible. According to the phantom study, scanning at 50 kV and 40 mA provides an image whose quality is statistically identical to the results obtained with 60 kV and 80 mA [2].

It can be concluded that tomosynthesis has been proven to be of higher diagnostic value for diagnosing and monitoring the progression of rheumatoid arthritis (compared to radiography) with an insignificant increase in dose. The clinical significance requires further study.

2. Specific and non-specific lesions and injuries of the spine

Tomosynthesis is widely used in the diagnosis of injuries and diseases of the spine. The experiment substantiated a method for assessing the state of the topography of the vertebral endplates, which requires clinical validation [3]. The efficiency of tomosynthesis for detection of vertebral compression fractures caused by osteoporosis has been demonstrated. By means of the studied method, at an average dose of 0.11 mSv, a significantly greater number of vertebrae are visualized and a significantly greater number of their fractures are also detected (Cohen's kappa coefficient of 0.73 for inter-expert agreement) [4]. It has been shown that overcoming the summation effect ensures fundamentally better visualization of the C1–C2 segment, small erosions and sharpenings of the vertebrae in the thoracic spine, spondylolysis of the vertebral arches in the lumbosacral region; more accurate diagnostics of osteochondropathy of the thoracic spine, spondylolysis and spondylolisthesis in the lumbar region becomes possible. It is noteworthy that tomosynthesis allows reliable visualization of the vertebral arches from both sides in one pass of the X-ray tube, which eliminates the need for additional examination and reduces the dose load on the patient [5]. In ankylosing spondylitis, tomosynthesis provides significantly better detection of minor lesions (erosions, sclerosis) of the vertebrae and facet joints, and more accurate diagnostics of the degree of ankylosis. In this cross-sectional diagnostic study, the Stoke Ankylosing Spondylitis Spine Score (mSASSS) was used as a metric, and a comparison was made with radiography [6]. However, the results of the presented studies are characterized by low homogeneity and relatively weak statistical analysis. The use of tomosynthesis for the diagnosis of tuberculous lesions of the spine has been studied most thoroughly.

Yu.A. Tsybulskaya et al. in 2015–2016 put forward a hypothesis that the technical characteristics of tomosynthesis potentially allow for more accurate visualization of destructive foci and sequesters in the vertebrae in tuberculous spondylitis, including those in locations that are difficult to access with standard radiography (spinous and transverse processes, vertebral bodies in the cervical spine) in comparison with standard radiography. A comprehensive study of the problem of radiation diagnostics of tuberculous lesions of the spine confirmed the hypothesis put forward by the authors.

In the spondylitic phase of tuberculous lesions of the spine, radiation research methods are used to determine the localization and extent of destructive bone changes, as well as to identify paravertebral abscesses. The capabilities of standard radiography are limited due to difficulties in visualizing small sequesters, as well as under unfavorable technical conditions of the study (for example, summation of intestinal loops). Computed tomography is free from these problems, but tomosynthesis represents a serious alternative in terms of lower radiation exposure and cost of examination [8]. As a result of the diagnostic study, standard radiography, computed tomography and tomosynthesis were compared (Table 2). Three types of vertebral body destruction were identified: subchondral, focal and mixed. The main radiation signs of spinal tuberculosis were determined during tomosynthesis, including mixed destruction of vertebral bodies ($p < 0.04$), pronounced anterior wedge-shaped deformation of the vertebral bodies ($p = 0.05$), rare damage to the transverse and spinous processes ($p = 0.05$). When performing tomosynthesis, depending on the area of study, the effective dose is 2 to 12 times higher than with standard radiography, and 2 to 11 times lower than with CT [8].

Table 2

Diagnostic value of various methods of radiation diagnostics in the detection of tuberculous spondylitis and paravertebral abscess [1, 27]

Index, %	Radiography		CT		Tomosynthesis	
Sensitivity, %	82,2	79,6	89,7	94,1	84,6	86,7
Specificity, %	76,1	82,5	84,0	89,1	79,3	84,0
Prognostic value of a positive result, %	69,1	–	76,5	–	78,6	–
Prognostic value of a negative result, %	87,1	–	91,3	–	85,2	–
Accuracy, %	78,4	89,7	85,0	91,3	81,8	85,5

In terms of diagnostic value, tomosynthesis occupies an intermediate position between CT and standard radiography, reliably surpassing the latter. The identified causes of false-positive and false-negative results are interesting. False-positive assessments occur when a tuberculous abscess is localized in the sacral region (at the level of SIII–SIV); it is noted that visualization is also reduced against the background of intestinal loops and with diffuse thickening of the iliopsoas muscle. False-negative results occurred with small sizes (up to 2–3 cm) of prevertebral abscess in the cervical region and with localization of abscesses in the thoracic spine [1]. It was noted that tomosynthesis is significantly inferior to CT in visualizing soft tissues, in particular, in 10% of cases of tuberculous lesions, abscesses were detected on CT scans that were not detected using standard radiography and tomosynthesis. To solve this problem, the authors proposed using a combined approach that simultaneously reduces the radiation load: using tomosynthesis to assess bone destructive changes and ultrasound to diagnose paravertebral abscesses. It was also found that there are no reliable differences in assessing the degree of osteoporosis between CT, standard radiography and tomosynthesis [2]. In general, similar results were obtained by D. Jiao et al. in 2016. When comparing standard radiography and tomosynthesis in 55 patients with tuberculous spinal lesions, it was found that the latter is more effective for detecting destruction, sequestration, and paravertebral abscesses, while both methods do not differ in accuracy for detecting changes in the intervertebral space [4]. Thus, in diagnosing tuberculous spinal lesions, tomosynthesis is superior to standard radiography in visualizing sequesters and other lesions of bone tissue. Data on the accuracy of detecting paravertebral abscesses are questionable. Compared to CT, tomosynthesis has lower diagnostic efficiency, but is a safer and less costly method [5]. Tomosynthesis can be considered as the method of choice in diagnosing and monitoring the progression of tuberculous spinal lesions. The significance of the method for screening osteoporotic compression fractures requires in-depth study.

3. Non-specific joint lesions and injuries Tomosynthesis is used to diagnose and monitor the course of osteoarthritis of the knee joint, injuries and post-traumatic instability of the foot joints.

In osteoarthritis of the knee joint, tomosynthesis demonstrates a significantly higher sensitivity in detecting osteophytes than radiography (94.0–100.0% and 71.0–75.0%, respectively); there is no difference between the methods in terms of specificity. The diagnostic accuracy of tomosynthesis is also slightly higher: 93.0–100.0% versus 83.0–93.0%. Tomosynthesis allows for more accurate detection of grade 1 osteophytes (according to the international classification of the Osteoarthritis Research Society), which are often missed with standard radiography. From a clinical point of view, such thoroughness can potentially provide a better interpretation of the causes of pain syndrome. However, there is no strong evidence for this. In identifying subchondral cysts, tomosynthesis does not have significant advantages over standard radiography [2].

A method for assessing the narrowing of the joint space of the knee joint by automated processing of images obtained by tomosynthesis (in a standing position, with a load on the knee joint) is proposed. Experimental validation of the method on a phantom and a preliminary assessment on clinical data were carried out [3]. The method seems promising for the diagnosis and monitoring of osteoarthritis (especially in the early stages), but requires further detailed study.

Diagnosis of injuries, post-traumatic instability, diseases of the joints of the foot (subtalar, talocalcaneonavicular, etc.) is extremely complex. The value of radiography in this case is low, and computed tomography allows only static examination. Against this background, it is tomosynthesis that makes it possible to qualitatively visualize the necessary anatomical structures with functional tests or load. Thus, the studied method is a significant alternative to computed tomography in the study of the foot. Separately, we note that the use of tomosynthesis made it possible to refine the data regarding the physiological range of motion in the subtalar joint: in healthy individuals, this range is 15 degrees [3].

The fundamental possibility of using tomosynthesis for radiation examination of joints with load and functional tests has been shown, which is extremely important for traumatology and orthopedics [4]. At the same time, tomosynthesis is characterized by a higher quality of diagnostic images than classical radiography. At the same time, comparative studies have not been conducted. Tomosynthesis can be positioned as a more accurate method for diagnosing osteochondropathy of the femoral head (Legg-Calve-Perthes disease) (Table 3). In patients with suspected osteochondropathy of the femoral head, the accuracy, sensitivity and specificity with standard radiography were 73.3%, 70.3% and 71.2%, and with tomosynthesis - 91.8%, 92.4% and 93.1%, respectively [5]. With tomosynthesis of the hip joints, it is possible to visualize the structure of the femoral head in more detail in one study, assessing both the anterior and posterior surfaces [2]. Tomosynthesis is superior in accuracy, sensitivity, specificity and other indicators to standard digital radiography, which makes it possible to recommend it as the method of choice in the diagnosis of osteochondropathy of the femoral head. Endoprosthetics of the knee and hip joints is the leading method of surgical treatment of a number of injuries and chronic diseases. Patients of the corresponding group require long-term, virtually lifelong observation, which poses special challenges for radiation diagnostics.

Table 3

Comparative radiological semiotics of Legg-Calve-Perthes disease using standard digital radiography and tomosynthesis [5]

Stage of	Standard digital radiography	Tomosynthesis

the disease		
I	No pathological changes in bone tissue were detected	Minimal compaction of the bone structure on the affected side (100.0%); cyst-like reorganization of the bone-trabecular structure of the subchondral part of the femoral head (75.0%); flattening of the inner pole of the epiphysis (17.0%)
II	Compression of the head and widening of the joint space (80.0%); absence of subchondral enlightenment (60.0%); compaction of the structure of the femoral head (40.0%)	Intra-articular effusion (100.0%); violation of congruence of the edge of the femoral head and acetabulum (80.0%); areas of osteonecrosis (60.0%)
III	Homogeneous darkening of the femoral head with the absence of its bone pattern (100.0%); shortening of the neck (60.0%)	Intra-articular effusion (100.0%); fragmentation of the head (90.0%); shortening and thickening of the femoral neck (70.0%)
IV–V	Subluxation of the femoral head outward (63.6%)	Subluxation of the femoral head outward (81.8%)
	The frequency of detection of other signs is the same	

4. Subtle fractures and dislocations

Minimizing projection overlaps in tomosynthesis creates unique prerequisites for diagnosing traumatic injuries to bones and joints that are barely noticeable in classical radiography. This eliminates the need for CT. Comparative studies of digital tomosynthesis and computed tomography or classical radiography were conducted using the material of several hundred patients with injuries to the extremities, femoral neck, knee, shoulder and ankle joints, nasal bones, orbit, jaws, spine, clavicle, sternum, pelvis and sacrum, hand (scaphoid bone), atlantoaxial joint [6].

CONCLUSION

Further study, primarily from a clinical standpoint, is required for the application of tomosynthesis for monitoring the course of chronic pathological processes (degenerative-dystrophic, rheumatic) in large joints, and reparative processes in the bone tissue of long bones of the extremities. The possibilities and significance of tomosynthesis in urgent traumatology should be studied with a detailed description of the localization and types of damage. Potentially, tomosynthesis can be used to develop methods for screening aseptic instability of endoprostheses (limitation - zirconium structures), monitoring the effectiveness of drug therapy (osteoarthrosis, rheumatoid arthritis), and screening for disorders of reparative regeneration of bone tissue.

REFERENCES

1. Tsybulskaya Yu.A. Modern clinical and radiation diagnostics of tuberculous lesions of the spine (literature review) // Medical Visualization. - 2015. - No. 1. - P. 59-68.
2. Yoo J.Y., Chung M.J., Choi B., Jung H.N., Koo J.H., Bae Y.A., Jeon K., Byun H.S., Lee K.S. Digital tomosynthesis for PNS evaluation: comparisons of patient exposure and image quality with plain radiography // Korean Journal of Radiology. - 2012. - Vol. 13, No. 2. - P. 136-143. DOI: 10.3348/kjr.2012.13.2.136.
3. Anari J.B., Mehta S., Ahn J., Kneeland B. The Utility of Digital Tomosynthesis to the Practicing Orthopedic Trauma Surgeon: A Case Series // Journal of Orthopedic Trauma. 2016. Vol. 30, No. 2. P. e59 e63. DOI: 10.1097/BOT.0000000000000445.
4. Machida H., Yuhara T., Sabol J.M., Tamura M., Shimada Y., Ueno E. Postoperative follow-up of olecranon fracture by digital tomosynthesis radiography // Japanese Journal of Radiology. 2011. Vol. 29, No. 8. P. 583 586. DOI: 10.1007/s11604-011-0589-3.
5. Machida H., Yuhara T., Tamura M., Ishikawa T., Tate E., Ueno E., Nye K., Sabol J.M. Whole-Body Clinical Applications of Digital Tomosynthesis // Radiographics. 2016. Vol. 36, No. 3. P. 735 750. DOI: 10.1148/rg.2016150184.

6. Roth E.S., Ha A.S., Chew F.S. Demystifying the status of fracture healing using tomosynthesis: A case report // Radiology Case Reports. 2015. Vol. 10, No. 3. P. 22 26. DOI: 10.1016/j.radcr.2015.06.011.
7. Gazaille R.E. 3rd, Flynn M.J., Page W. 3rd, Finley S., van Holsbeeck M. Technical innovation: digital tomosynthesis of the hip following intra-articular administration of contrast // Skeletal Radiology. 2011. Vol. 40, No. 11. P. 1467 1471. DOI: 10.1007/s00256-011-1247-7.
8. Mermuys K., Vanslambrouck K., Goubau J., Steyaert L., Casselman J.W. Use of digital tomosynthesis: case report of a suspected scaphoid fracture and technique // Skeletal Radiology. 2008. Vol. 37, No. 6. P. 569 572. DOI: 10.1007/s00256-008-0470-3.