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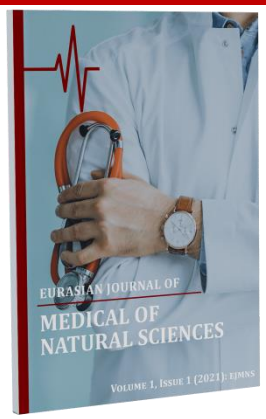

EFFECTIVENESS OF COMPUTER OPTICAL TOPOGRAPHY IN SCOLIOSIS

Sangilov Umid Bahtiyarovich
Assistant of the Department of Traumatology, Orthopedics and Neurosurgery of TashPMI
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ABSTRACT

This article explores the use of computer optical topography (COT) in the diagnosis, screening, and monitoring of patients with spinal deformities. COT is a safe and accurate method that avoids the use of radiation. Emphasis is placed on the method's advantages, including speed, precision, and the ability for dynamic observation. Limitations and development prospects, including integration with artificial intelligence, are also considered.

Introduction: Scoliosis is a complex orthopedic condition characterized by lateral curvature of the spine, leading to its rotation and deformation of the rib cage. According to the World Health Organization (WHO), approximately 2–3% of the population suffers from various forms of scoliosis. In the 10–16 age group, this figure rises to 10%, making the condition particularly relevant for adolescents. In some countries, such as the USA, over 600,000 patients seek medical care annually due to scoliosis, with 30% of cases requiring active treatment, including bracing or surgery (Scoliosis Research Society, 2023).

Advanced scoliosis results in not only aesthetic issues but also severe respiratory and cardiovascular system dysfunctions. Patients with severe forms often experience chronic pain, reduced physical activity tolerance, and a lower quality of life. Early diagnosis is therefore critical in preventing scoliosis progression.

Traditional diagnostic approaches are based on radiography, which measures curvature angles using Cobb's method. However, frequent use of radiological methods poses radiation exposure risks, particularly for children and adolescents. Studies indicate that repeated exposure to X-rays increases the risk of cancer (PubMed, 2021). These findings underline the necessity for alternative diagnostic methods that combine safety, accuracy, and accessibility.

Computer optical topography (COT) is an innovative technique based on analyzing the three-dimensional topography of the back surface. The technology uses projected light lines to create a detailed 3D model of the patient's spine, enabling scoliosis diagnosis and monitoring progression. Unlike radiography, COT is entirely safe for repeated use. Additionally, the method offers high accuracy and quick examination times, making it a convenient tool for both mass screening and dynamic patient monitoring.

Economic efficiency is another notable advantage of COT. Research indicates (Springer, 2022) that its use reduces diagnostic costs by eliminating frequent radiography. This is especially relevant for preventive checkups in schools, where annual examinations of hundreds of children require a safe and rapid diagnostic method.

Principles of Computer Optical Topography

Technical Description: Computer optical topography (COT) is a non-invasive diagnostic method based on the analysis of three-dimensional topography of the patient's back. The technology involves several key stages:

1. **Projection of Light Lines:** A structured grid of parallel light lines is projected onto the patient's back using a special projector. These lines distribute evenly across the skin but deform upon reflection due to body surface irregularities. These distortions reflect the anatomical features of the back, including spinal curvatures.
2. **Image Capture:** High-precision cameras, or multiple cameras placed at optimal angles, capture the reflected light lines. These images provide a comprehensive view of the back's surface.
3. **Data Processing:** The captured images are transmitted to specialized software, which interprets the distortions and transforms them into a three-dimensional model of the body surface. Key diagnostic parameters, such as Cobb's angle, shoulder asymmetry, pelvic tilt, and vertebral rotation, are calculated automatically.
4. **Analysis Results:** The final output is a detailed 3D model of the patient's back and corresponding numerical indicators. This information enables physicians to evaluate the severity of spinal curvature, track disease progression, and plan appropriate treatment.

COT ensures a fast examination process—taking only 5–10 minutes, including equipment setup and data interpretation.

Comparison with Radiography

COT has several advantages over traditional radiography:

1. **Absence of Radiation Exposure:** Unlike radiography, COT is entirely safe, allowing frequent examinations without health risks. This is particularly crucial for children and adolescents who require regular spinal monitoring.
2. **Three-Dimensional Visualization:** Radiography provides a two-dimensional image, limiting its diagnostic precision. In contrast, COT creates a 3D model, offering a more comprehensive view of spinal conditions.
3. **Convenience and Speed:** COT requires less time, involves no complicated patient preparation, and can be used for mass screening.

Despite its advantages, radiography remains indispensable for analyzing spinal bone structures, such as vertebrae, intervertebral discs, and pathological changes. Thus, the two methods are complementary.

Types of COT Systems

Various COT systems differ in operating principles, technical characteristics, and areas of application:

1. **Light Stripe Projection Systems:** These systems use distortions in projected light stripes to analyze the body surface's topography. Advantages include high accuracy and affordability. They are widely used in clinics for diagnosing and monitoring scoliosis.

2. **Stereophotogrammetric Systems:** Utilize multiple cameras capturing back images from different angles. Software combines these images into a single 3D model. These systems provide accuracy but require complex setup and higher costs.
3. **Laser Scanning Systems:** Employ laser beams to build three-dimensional models. These devices offer maximum precision but are significantly more expensive and require specialized operating conditions.
4. **Portable Devices:** Compact systems suitable for field use, such as mass screening in schools. They operate using built-in cameras and mobile software, offering ease of use and reduced cost.

Integration with Artificial Intelligence (AI): Modern COT systems increasingly incorporate AI algorithms for automated data analysis. The software enables not only the evaluation of current parameters but also the prediction of curvature progression based on dynamic data.

Advantages of Computer Optical Topography: COT stands out for several reasons, making it one of the most effective methods for diagnosing and monitoring scoliosis. Below are its clinical and economic benefits:

1. **Safety:** COT's lack of ionizing radiation is particularly significant for children and adolescents, enabling frequent spinal monitoring without health risks. Research indicates repeated exposure to X-rays increases cancer risks (PubMed, 2021). COT eliminates this risk, making it a preferred choice for preventive checkups in educational institutions.
2. **High Speed of Examination:** COT procedures typically take only 5–10 minutes, including equipment setup, scanning, and data processing. This is crucial for mass screening in schools or sports teams. Additionally, the method requires no extensive patient preparation, making it less stressful for children.
3. **Diagnostic Accuracy:** COT provides precise measurements, making it suitable for diagnosing early scoliosis stages and tracking its progression. Parameters assessed include:
   - Cobb's angle of spinal curvature,
   - Shoulder and pelvic asymmetry,
   - Vertebral rotation,
   - Overall back symmetry.

   These data are essential for planning treatments, such as bracing or surgical intervention.
4. **Dynamic Monitoring:** Regular COT assessments help:
   - Track scoliosis progression,
   - Evaluate treatment effectiveness (e.g., brace adjustments or rehabilitation),
   - Monitor postoperative outcomes.
5. **Suitability for Mass Screening:** COT's speed and safety make it ideal for preventive screenings in schools, sports clubs, and kindergartens. For instance, a UK screening program in 2021 used COT to examine over 10,000 schoolchildren, identifying early-stage scoliosis in 8% of cases, allowing timely intervention.
6. **Economic Efficiency:** Despite high equipment costs, COT reduces overall diagnostic expenses by:
   - Eliminating frequent radiography,

- Minimizing complication risks via early detection,
- Shortening examination times and increasing clinic throughput.

7. **Detailed Visualization:** The COT software creates detailed 3D back models, allowing:
   - Clear visualization of spinal curvatures,
   - Improved communication with patients and parents,
   - Enhanced treatment planning.
8. **Integration with Other Technologies:** COT can be combined with radiography, MRI, and CT for comprehensive spinal assessments. Additionally, AI-enhanced systems improve diagnostic precision by minimizing human error.

Clinical Applications of COT

Computer optical topography (COT) is widely used in orthopedics, rehabilitation, and preventive medicine. The method supports diagnosis, treatment planning, and monitoring. Key areas of application include:

1. **Screening and Early Detection of Scoliosis:** COT has proven effective for mass screenings of children and adolescents. It enables quick and safe examinations to identify even early scoliosis stages. For example, in Japan, school-based COT programs detected early scoliosis in 12% of examined children, preventing disease progression (Springer, 2022). Target groups include:
   - Schoolchildren and adolescents during growth spurts,
   - Children at higher risk of spinal deformities (e.g., due to heredity or poor posture),
   - Athletes subject to high spinal loads.
2. **Diagnosis and Clinical Assessment:** COT facilitates detailed spinal condition analysis. Based on the 3D model data, physicians can:
   - Determine spinal curvature angles,
   - Assess shoulder, pelvic, and chest asymmetry,
   - Detect vertebral rotation,
   - Analyze rib cage deformation.

   These findings aid in accurate diagnosis and staging scoliosis, forming the basis for treatment decisions.
3. **Monitoring Patients with Diagnosed Scoliosis:** Dynamic observation is crucial for managing spinal deformities. COT supports:
   - Assessing scoliosis progression via regular examinations,
   - Evaluating treatment effectiveness (e.g., bracing or physical therapy),
   - Monitoring post-surgical outcomes, ensuring proper spinal correction and recovery.
4. **Treatment Planning and Outcome Evaluation:** COT plays a pivotal role in treatment strategy development. Physicians use COT data to:
   - Design personalized conservative treatments (e.g., braces or physical therapy),
   - Plan surgical interventions by identifying exact curvature locations and methods for correction,
   - Assess surgical outcomes, including spinal realignment and symmetry restoration.
5. **Rehabilitation and Sports Medicine:** COT also serves as a tool for monitoring spinal health in athletes and patients undergoing rehabilitation. Applications include:
   - Detecting early signs of spinal strain in athletes,

- Evaluating the impact of training on biomechanics,
- Adjusting training programs to prevent injuries.

In rehabilitation, COT helps monitor exercise results, restore symmetry, and prevent posture-related issues.

6. **Examples of Clinical Use:**
   - **School Screenings in Finland:** Over 5,000 children were examined using COT, detecting early-stage scoliosis in 8% and avoiding later surgical interventions.
   - **Postoperative Rehabilitation in Germany:** COT in rehabilitation centers evaluated spinal correction and guided therapy adjustments.
   - **Athlete Monitoring in the USA:** COT systems helped monitor gymnasts' spines, prone to deformation under high physical loads.

Limitations and Challenges

Despite its many advantages, COT has limitations that must be considered in clinical practice. Key challenges include:

1. **Sensitivity to External Factors:** COT results can be influenced by:
   - **Lighting conditions:** Excessive or uneven lighting can disrupt image capture.
   - **Patient movement:** Movements during scanning distort projections, reducing data reliability.
   - **Equipment setup:** Improper camera calibration or positioning can yield incorrect results.

Strict adherence to procedural standards, including environment control and staff training, minimizes these risks.

2. **Lack of Standardized Results:** Different COT manufacturers use proprietary image processing algorithms, complicating result comparisons. Standardization efforts are needed to ensure consistent data interpretation, particularly in large-scale screening programs.
3. **High Equipment Costs:** The significant expense of COT devices limits accessibility for smaller clinics and resource-constrained regions. Additional costs include:
   - Equipment space and setup,
   - Staff training,
   - Ongoing maintenance.
4. **Limited Direct Bone Assessment:** While COT provides detailed surface analysis, it does not reveal bone structure conditions, such as:
   - Intervertebral disc changes,
   - Vertebral defects,
   - Degenerative issues.

   Combining COT with radiography, MRI, or CT is essential for comprehensive diagnosis.
5. **Accuracy in Certain Patient Groups:** Results may be less reliable for patients with obesity, pronounced posture abnormalities, or severe rib deformities due to projection challenges and software interpretation limits.

Prospects and Development of the Technology

Computer optical topography (COT) is a high-tech diagnostic method undergoing continuous advancements. Current research and developments aim to enhance accuracy, accessibility, and integration into clinical practice. Key development directions include:

1. **Integration with Artificial Intelligence (AI):** One of the most promising advancements involves using AI algorithms for data analysis. Modern AI systems can:
   - Recognize spinal curvature patterns,
   - Predict scoliosis progression based on dynamic data,
   - Minimize human error in result interpretation.

   Example: In 2022, Germany tested machine learning-based software, improving COT data analysis accuracy by 15% compared to traditional algorithms (Springer, 2022).
2. **Development of Portable Devices:** Compact and mobile COT systems are increasingly in demand, particularly for mass screenings in schools, sports clubs, or remote medical facilities. Benefits of portable systems include:
   - Ease of transportation,
   - Reduced examination costs,
   - Usability in field conditions.

   Example: Japan developed tablet-based devices connected to standard cameras for basic body surface analysis (Scopus, 2023).
3. **Integration with Electronic Medical Records (EMR):** Modern COT systems are starting to integrate with EMRs, enabling automatic storage of examination results and comparisons with previous patient data. This streamlines:
   - Dynamic patient monitoring,
   - Report generation for physicians,
   - Treatment planning.

   Example: In the USA, COT systems linked to national medical registries accelerate data analysis and improve inter-specialist communication (PubMed, 2022).
4. **Standardization of Data Analysis Protocols:** International organizations, such as the Scoliosis Research Society (SRS), are working on unified standards for COT data analysis, including:
   - Harmonized image processing algorithms,
   - Unified diagnostic criteria,
   - Standard methods for evaluating curvature angles and other parameters.

   Standardization will enhance data comparability and facilitate widespread adoption of COT in mass diagnostics.
5. **Improved Software Capabilities:** New software versions include advanced features, such as:
   - Simulation of corrective procedures (e.g., surgical correction),
   - Real-time visualization of changes,
   - Automatic classification of scoliosis severity.

   These improvements simplify diagnostic processes and increase accuracy.
6. **Expansion into Related Medical Fields:** Beyond orthopedics, COT has potential applications in:
   - **Neurology:** Assessing postural changes in neurological conditions like cerebral palsy,
   - **Rehabilitation:** Monitoring recovery from spinal injuries,
   - **Ergonomics:** Analyzing posture to prevent workplace-related disorders.
7. **Cost Reduction:**

Advances in technology are gradually lowering the cost of COT components, such as cameras and projectors, making the method more affordable for clinics with limited budgets. Mass production of inexpensive systems is expected to increase accessibility, even in smaller medical institutions.

Conclusion

Computer optical topography (COT) represents an innovative and safe method for diagnosing and monitoring scoliosis, offering significant advantages. Its absence of ionizing radiation, rapid examination process, and suitability for repeated use make COT indispensable in modern orthopedic practice.

COT is particularly effective in mass screening programs aimed at early scoliosis detection in children and adolescents. The method has also proven valuable for dynamic monitoring, treatment planning, and evaluating therapy outcomes. Combined with traditional methods like radiography, COT provides a comprehensive understanding of spinal conditions while minimizing health risks.

Despite existing challenges, such as dependence on external factors, high equipment costs, and a lack of international standards, the prospects for COT are promising. AI integration, portable device development, and data analysis standardization are set to expand its capabilities and accessibility.

Thus, computer optical topography is a promising tool for scoliosis diagnosis and monitoring. Its implementation in clinical practice enhances medical care quality and improves patient outcomes. Further research and technological innovations will maximize its potential in healthcare.

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