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CUSUM Learning Curve Analysis in Medical Imaging Education: A Review of Competency Assessment Research Progress

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Abstract

The rapid advancement of medical imaging technology has introduced significant challenges in the field of medical imaging education, particularly concerning the allocation of teaching resources, the evaluation of students' skill acquisition, and the need for innovative teaching methodologies. While simulation-based training and objective assessment tools have become increasingly common in medical education, there remains a notable lack of effective quantitative approaches to monitor and evaluate the development of students' diagnostic imaging competencies, especially in areas such as medical imaging report writing. This study aims to systematically review current developments in medical imaging education and the reform of instructional practices, with a specific emphasis on the application of the Cumulative Sum Control Chart (CUSUM) learning curve analysis in clinical skills training. Using a literature review methodology, this paper synthesizes relevant studies from both domestic and international sources to assess the role and potential of CUSUM in enhancing medical imaging education. The findings reveal that the use of CUSUM in this field is still limited, despite its strong potential as an objective, continuous method to assess student progress and identify learning plateaus or improvements. Furthermore, CUSUM analysis can inform the development of evidence-based, data-driven curricula that respond more effectively to learners' needs. Based on these insights, this study recommends the integration of CUSUM learning curve analysis into the framework of medical imaging education as a strategic approach to improve instructional quality, ensure objective skill assessment, and support the continuous improvement of educational practices in the digital age.

Keywords: *CUSUM, Learning curve, Medical imaging education, Simulation training system, Teaching assessment.*

A. Introduction

Training skilled medical imaging professionals in China, like in many other parts of the world, is a complex and lengthy process. For most medical students, especially those focusing on medical imaging, this subject is a required part of their studies, usually lasting one academic year or two semesters. Students not only need to grasp important theories but also must learn how to think critically and use medical language effectively to write clear diagnostic reports. This is mainly achieved through lots of practice with real imaging cases and writing reports—skills that are crucial in clinical settings.

One of the toughest challenges in training these students is teaching them how to accurately interpret medical images (Alamer & Alharbi, 2021). While online learning can be a helpful tool for teaching radiology, it often doesn't work well for large groups of students. There's also a need for standardized online medical education tools that are still being developed (Stoehr et al.,

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2021). Right now, we lack effective ways to measure the diagnostic skills of students who haven't yet had hands-on clinical experience.

To tackle this issue, educators at Zunyi Medical University started creating a tool called the Medical Imaging Diagnostic Skills Training Simulation System (MIDS) in 2015. This system uses clinical imaging data and mobile technology to help teachers assign cases, give tasks, assess student performance, and manage grades all through mobile devices. At the same time, students can practice interactively, receive further training, and take evaluations. MIDS has already been used by around 410,000 users, aiding both online and offline learning for many medical and imaging students.

Even with this progress, it remains unclear how much training is truly necessary for students to become competent in diagnostics. This uncertainty can lead to overly complicated course requirements that don't match what students actually need, wasting resources and causing unnecessary repetition in learning. By analyzing performance data collected through MIDS, educators can get better insights to adjust teaching methods and plan effectively.

One approach that can help in this analysis is called the Cumulative Sum (CUSUM) learning curve method, which has been around for over fifty years (Cavill, 1971; Riddick & Giddings, 1971). This method looks at how many times a person needs to practice a task to do it well. It's commonly used in clinical practice, particularly in training surgeons, and has proven to be very effective in these kinds of educational settings (Chua et al., 2021; Jimenez-Rodriguez et al., 2016; Woodall et al., 2021). However, its use in teaching students about diagnostic imaging is still largely unexplored.

This review aims to investigate how useful CUSUM analysis can be in improving medical imaging education, especially in developing skills needed for writing structured diagnostic reports. It also hopes to provide insights based on data to better shape course designs and make more effective use of educational resources.

B. Methods

This study employs a descriptive qualitative approach using a systematic literature review methodology. This design was selected to examine developments in medical imaging education and assess the potential application of the Cumulative Sum Control Chart (CUSUM) as a quantitative tool in clinical skills training, particularly in medical imaging report writing. A systematic literature review enables the integration of diverse findings into a coherent framework that can guide evidence-based educational reform (Siddaway, Wood, & Hedges, 2019).

The research procedure began with the identification of key issues related to the lack of objective quantitative assessment tools in medical imaging education. A structured search was conducted across academic databases, including PubMed, Scopus, Web of Science, and Google Scholar. Keywords such as "CUSUM," "learning curve," "medical imaging education," "clinical training," and "assessment methods" were used to retrieve relevant studies. Screening was performed based on inclusion criteria such as publication within the last ten years, peer-reviewed status, relevance to the topic, and availability in English (Page et al., 2021).

Inclusion criteria focused on peer-reviewed articles related to medical education, CUSUM applications, and simulation-based training. Exclusion criteria included grey literature, non-academic sources, and irrelevant topics. Selected studies were organized thematically to identify recurring patterns, research gaps, and practical implications.

Data were collected from secondary sources including academic journal articles, research reports, books, and conference proceedings. Conceptual frameworks related to clinical performance assessment and learning curve models were analyzed, with specific emphasis on the role of CUSUM in improving diagnostic skill acquisition (Vassiliou et al., 2005; Evans et al., 2006). The quality and credibility of each source were verified through relevance, citation impact, and peer-review status.

Thematic analysis was used to synthesize the data, identifying core themes such as current challenges in medical imaging education, the integration of simulation in training, and the underutilized potential of CUSUM as an objective, continuous assessment tool (Kirkpatrick & Lockhart, 2021). The findings offer evidence-based recommendations for incorporating CUSUM into curriculum design and student evaluation frameworks. This approach supports a more data-driven, adaptive, and learner-centered model for clinical education in the digital age.

C. Results and Discussion

1. Current Status of Medical Imaging Education

Medical imaging education at universities is advancing quickly and is essential for training future healthcare professionals. This part highlights the main elements that are influencing this changing field. These include the development of courses, the use of new technologies, hands-on training in clinical settings, and creative teaching methods.

Curriculum Design and Integration

Medical imaging courses at universities have recently undergone important updates to keep pace with new technologies in the field. These educational programs now focus more on providing thorough training in various imaging methods, such as X-rays, MRI scans, CT scans, and nuclear medicine. To help students better understand what they learn, these programs include practical exercises and real-world scenarios. This approach allows students to build both their knowledge and hands-on skills in diagnosis. Similar changes have also taken place in medical imaging education in China.

Technological Advancements and Simulation

More and more schools and training programs are using new technologies to improve education in medical imaging. Tools that simulate real-life situations and advanced imaging labs provide students with practice environments that mimic what they would experience in a hospital or clinic. These resources help students develop their skills in interpreting images and connect their classroom learning to real-world applications (Gunn et al., 2021; Hu et al., 2019; Martin et al., 2022).

Clinical Exposure and Internships

Getting practical experience is very important for students studying medical imaging. Many universities work together with hospitals and healthcare centers to give students chances to use what they've learned in real-life situations. This hands-on experience helps students deal with different medical tests and prepares them for their future careers.

Innovative Teaching Methods

As education evolves, schools and universities are using new teaching methods that focus more on students. Techniques like flipped classrooms, where students learn material at home and do activities in class, and problem-based learning, which involves solving real-world challenges, are becoming more common. These approaches make learning more engaging and help students think critically and learn on their own, skills that are essential for success in the quickly changing field of medical imaging.

2. Cumulative Sum (CUSUM) Learning Curve Analysis

The CUSUM learning curve analysis is a method that has been around for over 50 years and is used to assess how many practice attempts a person needs to become good at a specific task. Initially introduced in medical literature, this technique is particularly useful in areas like surgical training, where it helps track how well individuals are learning and improving their skills over time. CUSUM is valued for its ability to show trends in a learner's progress, identify when they might be stuck at a certain skill level, and provide immediate feedback on their performance. Many in the medical education field consider it a powerful tool for evaluating and improving competency in training programs. However, while CUSUM has been successful in various medical disciplines, it has yet to be applied to training for diagnostic imaging skills. This gap presents a great opportunity for further research and the use of CUSUM in this important area.

Future Research Perspectives in Medical Imaging

The use of artificial intelligence (AI) in medical imaging is becoming increasingly important, and educational programs need to change to keep up. In the future, we can expect that training for those entering this field will include the basics of AI, focusing on how these technologies work, the ethical issues they raise, and how human radiologists can work effectively with AI tools. Learning how to interpret data and use AI to enhance diagnostic accuracy will be a crucial skill for future professionals in medical imaging.

Virtual and augmented reality technologies are set to transform how we learn about medical imaging. In the future, educational programs could use these immersive technologies to help students explore anatomy, practice diagnosis in simulated scenarios, and work through case studies interactively. These tools create a realistic and engaging learning environment, which can improve understanding of spatial relationships and enhance decision-making skills.

The future of education in medical imaging will depend on teamwork between different fields. By creating training programs that combine medical imaging with areas like pathology (the study of diseases), genetics (the study of genes), and informatics (the use of information technology), we can prepare professionals with a wider range of skills. This approach recognizes how interconnected healthcare is today and helps ensure that those working in patient care have a well-rounded understanding of their roles.

The current state of education in medical imaging shows that advancements in technology have created a rich learning environment for students. However, as precision medicine continues to evolve, the introduction of new and complex imaging tools presents fresh challenges for educators in this field. One major challenge is the need to integrate various disciplines and technologies, which requires a deeper understanding of how to effectively diagnose medical conditions.

Looking ahead, our aim is to prepare medical imaging professionals who can accurately diagnose patients even as technology and medical knowledge grow more complex. These professionals will need strong problem-solving skills that cross various areas of medicine to keep up with the rapid pace of change. As the medical field evolves, more educators are recognizing the value of teaching through real-life clinical cases. Using modern tools and methods, such as analyzing how students learn over time, can help bridge the gap between hands-on case studies and intricate teaching methods.

3. Synthesis and Reflection

A look at current research shows that education in medical imaging is starting to change. Instead of focusing mainly on traditional lectures and theory, there's a growing emphasis on hands-on skills and the use of new technology. Many studies highlight the importance of developing practical skills, using simulation training, and collaborating across different fields of study. However, when it comes to evaluating students' progress, many programs still depend mostly on personal judgments or occasional tests. This means they often lack continuous and objective ways to measure how well students are developing their skills.

One method that has shown promise in areas like surgery is called the CUSUM method, which helps track learning and skill improvement over time. It systematically identifies key moments in the learning process and helps instructors see when a student's skills are stabilizing. This could be particularly useful in medical imaging education, which requires both knowledge and technical skills.

Interestingly, the use of the CUSUM method in this field has not been widely explored yet. Many existing teaching programs do not take advantage of tracking students' progress in a structured way. While some simulation training tools are available, there's a lack of consistent assessment methods that can be repeated and relied upon. By combining the CUSUM approach with smart teaching platforms, schools could create more personalized learning experiences and improve their curriculum based on real data.

Additionally, although some studies have talked about advancements in imaging technology, especially with the use of artificial intelligence and virtual reality, there hasn't been much focus on how educators assess student progress or how learning loads impact students' understanding. Future research should pay more attention to how teaching tools, evaluation methods, and the psychology of learning all work together in education.

D. Conclusion

This review looks into the current situation and challenges in teaching medical imaging, noting a shift from traditional theory-based lessons to more hands-on and technology-driven methods. One promising approach is the CUSUM (Cumulative Sum) learning curve method, which allows for real-time monitoring of students' progress during training. This could be particularly useful for teaching students how to make accurate diagnoses. However, it's still mostly in the experimental stage. By combining CUSUM analysis with advanced simulation tools like MIDS, educators could track how students are improving visually and adjust their teaching plans to better suit individual learning needs. This data-driven method could enhance traditional teaching by providing more effective feedback and better use of resources. In conclusion, using CUSUM learning curves in medical imaging education not only helps assess student performance in a more structured way but also represents an important move towards more evidence-based teaching methods. This is an area that deserves further attention in future research and teaching practices.

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