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Unforeseen Anomalies in Blood Smears: A Simulation-Based Training Study for Medical Biology Residents

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Abstract | **Original Research Article**

Background: This study investigates the value of integrating medical simulation as an educational tool for biology residents, addressing the critical need for safe, comprehensive training for medical practitioners, particularly in acquiring technical and non-technical skills for rare and complex medical procedures. A retrospective analytical study was conducted across two workshops for medical biology residents at the Faculty of Medicine' Simulation center in Tangier. ***Method:*** The methodology employed a structured training approach: initial pre-debriefing with pre-tests, a theoretical briefing utilizing the MEDCARE method, a hybrid simulation incorporating procedural and audiovisual components, dedicated debriefing sessions, and subsequent post-training evaluations. ***Results:*** The results showed a significant improvement in both theoretical and practical knowledge, with the average correct answer rate increasing from 65.20% before the training to 93.75% afterward. Participants became better at diagnosing, recognizing anomalies, and making decisions. The training achieved "High Fidelity Simulation" according to Alinier's model, and all participants were satisfied.

Keywords: Medical biology, Resident training, Hybrid simulation, Cytology.

INTRODUCTION

Medical simulation creates realistic clinical scenarios to teach diagnostic and therapeutic procedures safely and effectively. This approach helps learners gain both practical skills and soft skills, like communication and teamwork, in a controlled environment [1].

The integration of high-fidelity simulation has demonstrably improved learning outcomes, particularly in complex medical scenarios such as unstable cardiac arrhythmias and the management of pulmonary function in critical care settings [2].

The educational approach in medical training has shifted from the traditional "see one, do one, teach one" model to a more comprehensive "see one, simulate many, teach few" method. This change emphasizes practicing and mastering skills in simulated settings before working with actual patients, thus improving clinical ability and reducing accidental harm [3].

Simulation-based education offers a safe, controlled environment for students to gain confidence and competence, facilitating the acquisition of knowledge and improving attitudes toward clinical practice while protecting patients from unnecessary risks [4].

1. Current Challenges in Cytology Training

Traditional cytology training often relies on apprenticeships and passive observation, which may not adequately prepare trainees for the diverse and often subtle cellular abnormalities encountered in clinical practice, highlighting the need for more structured and interactive approaches [5]. Furthermore, the scarcity of rare or complex cases can limit exposure, making simulation an invaluable tool for replicating such scenarios and ensuring comprehensive skill development [6,7]. Consequently, simulation-based training offers a secure and controlled environment for residents to develop essential technical and non-technical skills in cytology without the cost constraints often associated with high-fidelity simulators [8]. This approach addresses challenges related to patient availability and

standardization in traditional learning, shifting medical training towards a model of extensive practice and mastery [9]. By integrating simulation into medical education, institutions can standardize training, ensuring all residents achieve a consistent level of proficiency and competency in cytology, irrespective of their exposure to specific clinical cases [10,11]. This method is particularly crucial for complex procedures such as Pap smear training, where low-cost anatomical models or advanced simulators can provide realistic, risk-free practice environments, thereby improving diagnostic accuracy and patient outcomes [12].

2. Traditional approaches to cytology and blood smear interpretation training face several significant limitations:

- Residents see few rare cell types, missing important findings.
- Patient safety and time limits mean residents get little hands-on practice.
- Training varies widely between different rotations and hospitals.
- The pressure of real patient cases can hinder learning.

3. Rationale for Simulation in Hematology Education

Because residents must learn a wide range of cellular morphologies and make critical diagnostic decisions, biological hematology poses special educational challenges. Incorrectly interpreting blood smears can severely affect a patient's diagnosis, prognosis, and treatment plan. Thus, it is vital to offer residents thorough, risk-free training opportunities to cultivate proficient healthcare professionals.

In laboratory medicine, medical simulation offers several advantages:

- Provides standardized exposure to a range of cell appearances, common and rare.
- Allows for repeated practice without time or patient safety concerns.
- Offers quick feedback to correct misunderstandings.
- Helps develop the pattern recognition needed for accurate diagnosis.

4. Study Objectives

This study aims to evaluate the integration of medical simulation as an educational tool in biological hematology resident training. Specific objectives include:

1. To assess the effectiveness of simulation-based workshops in improving residents' knowledge of blood smear interpretation
2. To evaluate changes in resident confidence levels regarding cytological analysis
3. To examine participant satisfaction with simulation-based learning methods
4. To analyze the practical applicability of simulation training to real laboratory settings.

MATERIALS AND METHODS

1. Study Design and Setting

The training took place at the Simulation Center at the Faculty of Medicine and Pharmacy of Tangier. This center, operational since the 2017-2018 academic year and moved to its current modern facility in 2020-2021, offers resources for simulation-based learning for student-doctors in training, and healthcare professionals.

1.1 Study Period

The study encompassed two distinct workshops held between May 9, 2023, and May 16, 2023. Each workshop spanned a single day, comprising 6 hours of intensive training.

1.2 Training Topics

The two workshops focused on critical aspects of hematological cytology:

- "Interpretive Reading of Blood Smears"
- "Unexpected Anomalies in Blood Smears"
- The overarching theme for both was "Cytology anomalies."

2. Participants

The study population included all medical biology residents across various years of their curriculum, assigned to different medical biology departments of the Faculty of Medicine and Pharmacy of Tangier, as well as specialists undergoing an equivalency internship period.

3. Training Intervention: Simulation Workshop Design

The training intervention consisted of two comprehensive simulation workshops designed to enhance both technical and non-technical skills in medical biology residents. Each workshop contained five distinct phases: pre-debriefing, theoretical briefing, hybrid simulation, debriefing, and post-training evaluation.

3.1 Scenario Development

Trained instructors in both clinical practice and simulation pedagogy developed the simulation scenarios. Leveraging the advanced resources of the simulation center and the expertise from the hematology laboratory service of the Mohammed VI University Hospital Center in Tangier, the design aimed for "High Fidelity Simulation" according to Alinier's 2007 framework.

3.1.1 Technical Objectives:

- Identifying artifacts: Telling the difference between real cell problems and things that are not.

- Recognizing blood parasites: Spotting signs of parasites in blood cells.
- Recognizing abnormal cells: Telling apart normal cells from cancer cells and other non-blood cells.
- Interpreting unclear results: Figuring out what ambiguous or unusual findings mean.
- Making decisions: Planning the next diagnostic steps when unusual results appear.

3.1.2 Non-Technical Objectives

- Flexibility and adaptability: Being able to react and adjust to unexpected situations.
- Improved decision-making: Getting better at making choices when things are uncertain.
- Interdisciplinary communication: Working well with others from different fields.
- Critical thinking: Thinking carefully to check information and avoid mistakes.

3.1.3 Trainers and Roles

The training team included two medical biology professors who led the discussion sessions. A former resident facilitated, guiding participants to ensure prompt, structured feedback essential for refining skills and consolidating knowledge, particularly in challenging areas like blood smear interpretation. The simulation approach emphasized both technical and non-technical skills throughout the scenario and discussion, fostering a comprehensive learning experience aligned with best practices in healthcare simulation, where clear learning objectives and structured debriefing are crucial for effective knowledge transfer and skill development.

3.1.4 Environment and Resources

Training materials included: hemogram results, visualized blood smear results from atypical cases, and associated clinical patient information. Synthetic blood pouch samples were also used for the procedural simulation.

3.1.5 Constraints

A known limitation was the lack of a microscope connected to a screen, which hindered collective viewing of slides and real-time focus adjustments. Consequently, there was a greater reliance on pre-prepared images for audiovisual simulation.

3.2 Workshop Procedure

Each 6-hour workshop followed a standardized five-part sequence:

3.2.1 Part I: Pre-debriefing and Pre-assessment

The training began with a pre-test to assess their baseline knowledge. This assessment, administered through Google Forms with multiple-choice or short-answer questions, helped identify specific training needs.

3.2.2 Part II: Briefing and MEDCARE Method

The training began with a 40-minute theoretical briefing, presented using the MEDCARE method to introduce participants to the session's context. MEDCARE is an acronym for M aterial, E nvironment, E thics, C ontext, A nticipation, R eassurance, and E xplanation. The general and specific learning objectives, along with the session's structure, were clearly outlined. This approach ensured participants understood the simulation's scope and expectations, creating a conducive learning environment [13]. This preparation is vital for establishing psychological safety and aligning learners with the simulation's educational goals [14]. By providing comprehensive information and reassurance, the preparatory phase is key to maximizing engagement and learning during the simulation activities [15].

3.2.3 Part III: Hybrid Simulation Activity

The practical phase involved a hybrid simulation approach:

- **Procedural Simulation:** Repetition of technical gestures focusing on preparing blood smears. *(Fig 1)*
- **Audiovisual Simulation:** Using microscope images, residents were trained to recognize different cell types and unusual cellular features linked to various medical conditions. This blended method enhanced skill development comprehensively.

Figure 1: Participants preparing blood smears for Workshop 1

3.2.4 Part IV: Debriefing

After the simulation, trainers led structured, chronological debriefing sessions. These sessions reviewed clinical cases and biological situations related to the workshop, guiding participants to develop action plans based on what they learned. The debriefing focused on key concepts, introducing new terms based on current guidelines, and encouraging critical thinking.

3.2.5 Part V: Post-training Evaluation and Follow-up

After each session, the training and the learners were thoroughly evaluated. Participants anonymously completed a questionnaire to gauge their learning and satisfaction. Furthermore, the practical impact was assessed by summarizing the ability of residents in the hematology laboratory service to apply established protocols post-training, with the goal of achieving Alinier's Level 3 realism in application.

4. Data Collection and Assessment

4.1 Knowledge Assessment

Theoretical and practical knowledge were assessed using pre-tests administered before the workshops and post-tests distributed after the sessions, conducted via Google Forms.

4.2 Satisfaction Evaluation

Participant satisfaction with the training was measured through an anonymous questionnaire distributed after each session.

4.3 Application of Guidelines

The ability of residents to apply established guidelines at the Hematology Laboratory service post-training was also assessed as part of the overall evaluation.

5. Statistical Analysis

The statistical analysis employed descriptive statistics and the analysis of various tables. Data entry and analysis were performed using Excel Office 2019 software.

RESULTS

1. Participant Demographics and Characteristics

The study population comprised residents across various years of medical biology training and specialists undergoing equivalency internships. Specifically, 51% were residents currently training in hematology laboratories, 47% were medical biology residents assigned to other laboratory services, and 2% were medical biology specialists in an equivalency training program.

Gender distribution varied between the two workshops:

- **Workshop 1:"Interpretive Reading of Blood Smears":** Demonstrated a female predominance with a sex ratio of 0.36 (male/female).
- **Workshop 2:"Unexpected anomalies in Blood Smears":** Showed a male predominance with a sex ratio of 1.09. The overall average age of participants was 30 years, ranging from 26 to 36 years.

2. Assessment of Theoretical and Practical Knowledge

2.1. Pre-test Evaluation Findings

Prior to the simulation workshops, a pre-test assessed participants' baseline theoretical and practical knowledge.

- **Question 1:** 100% of participants provided a definition of cytology. However, 43.5% focused on its clinical aspect, while 56.6% considered its broader role across all living organisms.
- **Question 2:** A high proportion, 95.7%, correctly identified the interest of cytological study, with 4.3% providing an incorrect response.
- **Question 3:** Participants cited various unexpected anomalies, including bacterial contamination, presence of atypical cells, hemorrhages, staining defects, air bubbles, debris, and the presence of red blood cells in a liquid. The assessment indicated that only one of the provided options was considered definitively correct among the given choices, but specific details on which one were not recorded here.

2.2. Post-test Evaluation Findings

Following the simulation training, a post-test was administered to evaluate knowledge acquisition and retention.

- **Question 1:** (Extra-hematopoietic, Metastatic, or "Overload Cells"): 90% of responses were correct, with 10% incorrect.
- **Question 2:** 83.3% of participants selected the two correct options. The document notes that these correct selections were chosen at similar percentages (specific values would enhance clarity), while 16.7% provided an incorrect response.
- **Question 3:** 100% of participants provided correct answers.
- **Questions 4, 5, and 6:** 100% of responses concerning parasites such as *Toxoplasma*, *Leishmania*, *Trypanosoma*, and *Plasmodium* (malaria), and their potential to alter blood cytology, were correct.
- **Question 7:** 83% of responses regarding appropriate diagnostic techniques were correct, with 17% deviating from established norms.

3. Overall, Knowledge Improvement *(Fig 2)*

A significant improvement in theoretical and practical knowledge was observed between the pre- and post-tests. The average correct response rate across all evaluated questions increased from 65.20% in the pre-test (first workshop) to 93.75% in the post-test (second workshop).

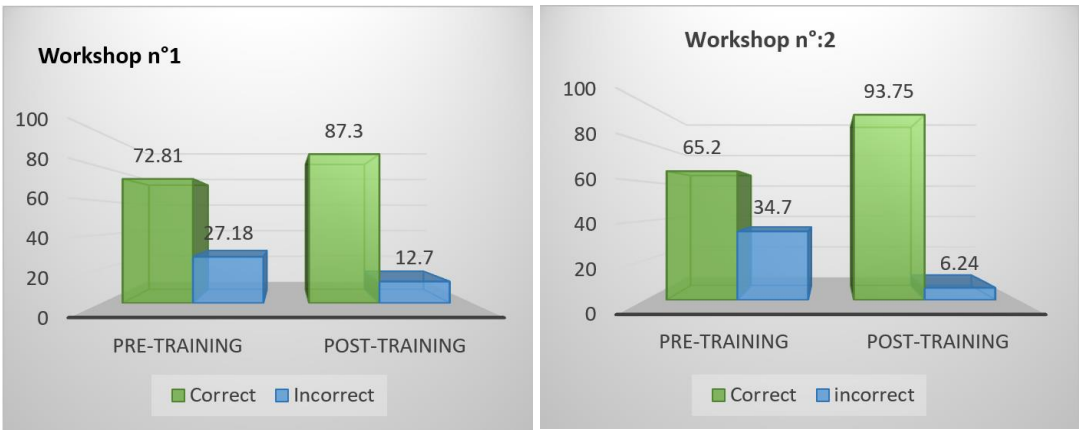

Figure 2: Evaluation of the participants in the pre- and post-training

4. Participant Satisfaction

Evaluation of participant satisfaction with the training revealed highly positive feedback. While only two-thirds of participants responded to the satisfaction questionnaire, 100% of these responses indicated a positive experience.

DISCUSSION

This study investigated the effectiveness of integrating medical simulation as an educational tool for medical biology residents, focusing on the acquisition of essential technical and non-technical skills in a safe environment. The findings align with previous research highlighting the efficacy of simulation in enhancing diagnostic accuracy and confidence, particularly in complex or rare cases [16]. The results indicate that simulation-based training significantly enhances residents' knowledge, practical skills, and self-confidence, aligning with similar studies in various medical fields [17,18].

Enhanced Knowledge Acquisition and Positive Feedback

Our findings reveal a significant enhancement in both theoretical and practical knowledge among participants, alongside universally positive feedback regarding the training experience. The average correct response rate notably increased from \$65.20% in the pre-test to \$93.75% in the post-test, demonstrating the immediate impact of the simulation workshops on learning outcomes. This aligns with previous research indicating that simulation-based training can significantly improve knowledge acquisition and practical skills in healthcare professionals [19]. For instance, studies have consistently shown that simulation enhances the understanding and application of critical appraisal concepts, reinforcing didactic learning with practical scenarios [20].

Benefits of Simulation-Based Medical Education

The significant improvement in knowledge and diagnostic skills observed is consistent with the well-documented advantages of simulation-based medical education [21,22]. Studies have shown that simulation training enhances participants' scores in knowledge and objective structured clinical examinations, underscoring its pedagogical value [23]. This supports findings that simulation is more effective than traditional lectures for learning and motivation across various medical fields, including human parasitology [24]. Simulation provides a safe environment for repeated practice of complex procedures and decision-making, crucial in medical biology where accurate interpretation and rapid response are vital for patient safety [25]. The iterative nature of simulation also creates an engaging learning environment, boosting motivation and deepening understanding of technical skills [26,24].

Participant Satisfaction and Engagement

Moreover, the high satisfaction rates among participants further underscore the perceived value and engagement fostered by simulated learning environments [27,14]. The positive outcomes observed here are consistent with other studies that have shown significant knowledge gains and improved critical thinking through simulation-based training [19,2].

Structured Workshop Approach and Active Learning

The structured nature of our workshops, comprising pre-debriefing, theoretical briefing, hybrid simulation, and post-simulation debriefing, fostered an active learning process crucial for deep understanding and skill transfer. This multifaceted approach ensures that learners not only acquire technical competencies but also develop critical non-technical skills such as

teamwork and communication, vital for effective clinical practice [7].

Theoretical Framework: Kolb's Experiential Learning Cycle

Our simulation program aligns with theoretical frameworks such as Kolb's Experiential Learning Cycle [28]. Our results support prior research demonstrating the effectiveness of simulation-based training in improving knowledge retention and practical skills across various medical disciplines [18,17]. Through a cycle of experiencing, reflecting, conceptualizing, and experimenting, residents internalized new knowledge and applied it. By participating in simulated clinical scenarios, they practiced learned skills, enhanced their critical thinking, and made decisions, receiving immediate feedback and structured guidance [22].

Integrating Technical and Non-Technical Skills

This multifaceted approach ensures learners acquire technical competencies and develop critical non-technical skills like teamwork and communication, vital for effective clinical practice [29]. This aligns with Kolb's model, where learners engage in concrete experiences within the simulation, reflect on their actions during debriefing, conceptualize new strategies, and actively experiment in subsequent scenarios, reinforcing their learning [24]. This approach to medical education, which includes parts of Kolb's Experiential Learning Cycle and different simulation methods, has effectively helped residents improve both their practical skills and important non-technical abilities [30]. These educational programs, especially those with situational simulations, are consistently effective in improving clinical skills and knowledge in complex medical settings, helping residents connect theory to practice [27,31]. The integration of real-world experiences, case-based discussions, and simulated environments effectively mirrors Kolb's learning cycle, strengthening the overall learning effect [30].

Role-Playing and Feedback for Skill Refinement

Moreover, role-playing exercises and immediate, constructive feedback likely improved learning by encouraging active participation and allowing for timely skill refinement. This approach has been effective in other training programs [32].

High-Fidelity Simulation and Competency Development

Furthermore, the design and implementation of our simulation scenarios aimed for "High Fidelity Simulation," as conceptualized by Alinier [33]. This level of realism promotes not only the acquisition of technical skills but also fosters essential non-technical competencies such as adaptability, critical thinking, decision-making under uncertainty, and interdisciplinary communication – skills vital for future medical biologists [34,7]. The engagement of participants in teamwork and their collective efforts towards common goals during the simulation further underscore its efficacy in promoting collaborative practice [1].

Validation of Advanced Simulation Methodologies

The 100% positive participant satisfaction rate underscores the perceived value and engagement generated by this high-fidelity approach, indicating that the training met or exceeded learner expectations [35]. This positive reception further validates the integration of advanced simulation methodologies into medical curricula, particularly for disciplines requiring precise diagnostic acumen [1,36].

Bridging Academic and Professional Demands

Our study highlights the importance of simulation in medical biology, enhancing diagnostic skills, improving interpretation of uncertain results, and refining decision-making processes, bridging the gap between academic and professional demands. This aligns with previous research indicating that experiential learning, particularly through high-fidelity simulations, bridges the gap between academic learning and professional demands by offering realistic scenarios [37].

Limitations

This study has several limitations. It was a retrospective analytical study conducted at a single institution with a relatively small sample size, which may limit the generalizability of our findings. Future research involving larger, multicenter cohorts would strengthen the external validity of these results and allow for more robust statistical analyses.

Future Research Considerations

Additionally, the long-term retention of knowledge and the direct impact on patient outcomes were not assessed within the scope of this study. [5].

CONCLUSION

Despite these limitations, our findings strongly advocate integrating a well-structured, high-fidelity medical simulation programs in the training of medical biology residents. Such programs are instrumental in equipping future healthcare professionals with the critical technical and non-technical skills necessary to navigate complexities and urgency of medical biology, ultimately enhancing patient safety and ensuring the highest quality of care. Further research with larger, multi-center cohorts and long-term follow-up is needed to confirm these benefits and explore the impact on clinical practice.

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