



Low-cost simulator for gastroschisis: an educational proposal for teaching neonatal surgery

Simulador de bajo costo para gastrosquisis: propuesta educativa para enseñanza de cirugía neonatal

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ABSTRACT

Introduction: Abdominal wall defects are congenital anomalies that require immediate neonatal management. Low-cost simulation constitutes an accessible alternative for training students and professionals in resource-limited settings. **Methods:** A methodological study for the development and validation of a simulator. A model (gastroschisis) was constructed using materials readily available in the Cuban market. Validation was carried out using expert criteria (n = 5) through a Likert scale to assess realism, educational utility, and feasibility. Thirty fourth-year medical students participated. Content Validity Indices were calculated. **Results:** The total cost of the simulator was 1950 CUP / 3,93 USD. Experts assigned average scores higher than 4,5/5 in all categories (global CVI 94,2 %). Of the students, 86,7 % considered that the simulator improved their understanding of initial management. There were no significant differences between the evaluations of experts and students (p > 0.05). **Conclusions:** The proposed simulator is feasible, low-cost, and valid as an educational tool for teaching the neonatal management of abdominal wall defects. Its implementation in undergraduate education can contribute to improving the preparation of future physicians for primary care.

Keywords: medical education; simulated training; gastroschisis; technological innovation; teaching materials; neonatology.

RESUMEN

Introducción: Los defectos de pared abdominal son anomalías congénitas que requieren manejo neonatal inmediato. La simulación de bajo costo constituye una alternativa accesible para la formación de estudiantes y profesionales en contextos con recursos limitados. **Métodos:** Estudio metodológico de desarrollo y validación de simulador. Se construyó un modelo (gastrosquisis) con materiales de fácil adquisición en el mercado cubano. Se realizó validación por criterio de expertos (n = 5) mediante escala Likert para evaluar realismo, utilidad educativa y factibilidad. Participaron 30 estudiantes de 4to año de Medicina. Se calcularon Índices de Validez de Contenido. **Resultados:** El costo total del simulador fue de 1950 CUP / 3,93 USD. Los expertos otorgaron puntuaciones promedio superiores a 4,5/5 en todas las categorías (IVC global 94,2 %). El 86,7 % de los estudiantes consideró que el simulador mejoró su comprensión del manejo inicial. No hubo diferencias significativas entre las evaluaciones de expertos y estudiantes (p>0.05). **Conclusiones:** El simulador propuesto es factible, de bajo costo y válido como herramienta educativa para la enseñanza del manejo neonatal de defectos de pared abdominal. Su implementación en el pregrado puede contribuir a mejorar la preparación de los futuros médicos para el primer nivel de atención.

Palabras clave: educación médica; entrenamiento simulado; gastrosquisis; innovación tecnológica; materiales de enseñanza; neonatología.

INTRODUCTION

Clinical simulation has been established as a fundamental pedagogical strategy in health profession education. This technique allows procedures to be repeated in a controlled environment, free of risk to the patient, and facilitates the acquisition of technical skills and clinical reasoning. However, commercial high-fidelity simulators cost between \$324 and \$500 per unit, which limits their availability in institutions in low- and middle-income countries. (1)

Abdominal wall defects are among the most common congenital surgical anomalies during the neonatal period. Gastroschisis, specifically, is a congenital abdominal wall defect characterized by the protrusion of intestinal loops through a defect lateral to the umbilical cord, without a protective sac. It has an incidence of approximately 1 in 2,000 live births, and its frequency has increased globally in recent decades. (1,2)

Initial management during the first minutes of life largely determines the patient's prognosis. Neonates must be able to 1) protect the exposed intestines with moist sterile compresses, 2) prevent hypothermia, 3) place an orogastric tube for decompression, and 4) stabilize the newborn for transfer to a referral surgical center. (2,3)

In Cuba, the healthcare system is organized under the principle of regionalization of neonatal care, where municipal and provincial hospitals stabilize patients before they are referred to specialized tertiary centers. This model assigns general practitioners and neonatologists crucial responsibility in the chain of survival. (4) However, practical training in these procedures faces limitations because of the scarcity of commercial simulators and ethical restrictions on practicing on real patients. (1)

Low-cost simulation has emerged as an effective response to this challenge. Research on low-cost simulations in medical education has significantly increased, particularly in the surgical field. Nevertheless, fewer than half of published studies report the costs of their models, and only a minority conduct formal validation processes. (5) Despite these advances, there is a knowledge gap regarding the formal validation of low-cost gastroschisis simulators adapted to the Cuban context and its available resources.

The hypothesis was proposed that a gastroschisis simulator constructed with low-cost local materials would be valid in content and useful as a teaching tool for instructing the initial management of a newborn with this defect. The primary objective was to develop and validate a low-cost gastroschisis simulator. The secondary objectives were to evaluate its educational utility from the perspective of experts and students and to compare the assessments of both groups.

METHODS

A methodological study on the development and validation of educational technology was conducted, structured in three phases according to the model by Polit and Beck: 1) development and construction of the simulator, 2) validation by experts, and 3) evaluation by students. (6)

Following the methodology proposed by the WALL-GO study (1), the following were established as minimum requirements for the simulator: (a) represent a newborn, (b) show the presence of the navel, (c) display the abdominal wall defect characteristic of gastroschisis (right side), (d) represent the exposed intestinal loops without a protective sac, and (e) allow for the practice of protective maneuvers.

Priority was given to materials easily available on the Cuban market (craft stores, pharmacies, industrial markets):

Phase 1: Development and construction of the simulator.

- Preparation of the base: A circular incision 4 cm in diameter was made on the right side of the abdomen at the paraumbilical level, with respect to the location of the simulated umbilical cord.

- Preparation of the intestinal loops: Condoms were filled with moistened polyurethane foam and tied at the ends. To simulate the edema characteristic of gastroschisis, a layer of lubricating gel dyed with pale yellow dye was applied.

- Fixation: The loops were attached directly to the edges of the defect, leaving them exposed and hanging outward, mimicking the appearance of gastroschisis (without a protective sac).

- Finishing: Makeup and talcum powder were applied to obtain the appearance of a newborn. Vascularization details were added using diluted red paint on the loops.

Component	Selected Material	Source
Neonatal torso	30–40 cm toy doll	Home
Leather	Stretch fabric	Home
Intestinal loops	Latex condoms filled with moist foam	Pharmacy
Simulated moisture	Lubricating gel mixed with yellow dye	Pharmacy
Simulated blood	Red food coloring mixed with flour and water	Home
Umbilical cord	Latex-coated cotton cord	Home
Fastening	Thread, needle	Home

A functional gastroschisis prototype was constructed featuring edematous intestinal loops emerging through a right lateral defect, the absence of a protective sac (characteristic of gastroschisis), manipulable loops that allow for the application of wet compresses, and a preserved and visible umbilical cord. (Figures 1, 2, and 3)

Figure 1. Lateral view of the neonatal torso with the right lateral defect and exposed intestinal loops. An intact umbilical cord is visible.



The cost of materials per unit was 1,950 CUP. This includes only the supplies described and excludes labor costs. At the most recent official exchange rate (1 USD = 496 CUP), this cost is equivalent to 3.93 USD, which is significantly lower than the 324–500 USD for commercial simulators. The torso and the defect can be reused indefinitely. Owing to their disposable nature (condoms, lubricant gel), the intestinal loops require replacement every 5–6 uses, which entails an additional maintenance cost of approximately 150 CUP (0.30 USD) per replacement.

Phase 2: Expert Validation

Five specialists with experience in neonatology, pediatric surgery, or medical education were invited to participate. This sample size was considered sufficient for the content validation of a new instrument, according to recommendations by Lynn (7), who suggested a minimum of 5–10 raters. The inclusion criteria were based on the adapted scoring system by Fehring (8):

Criterion	Score
Specialty in Neonatology or Pediatric Surgery	2 points
Master's or Doctoral Degree	2–4 points
Publications on simulation or congenital defects	4 points
Undergraduate teaching experience	2 points
Clinical experience > 5 years	1 point
Minimum score for inclusion	≥ 5 points

Figure 2. Top view of the simulator.



Figure 3. Close-up view of the intestinal loops.



The experts evaluated the simulator using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) on 7 statements adapted from the low-cost simulation validation study:

- Item 1: The simulator accurately represents the appearance of a newborn with gastroschisis.
- Item 2: The intestinal loops have a texture and color similar to reality.
- Item 3: The abdominal wall defect (right side) is anatomically correct.
- Item 4: The simulator allows users to practice the initial steps (protection, moistening).
- Item 5: The material is durable enough for multiple uses.
- Item 6: The simulator is useful as a teaching tool in undergraduate education.
- Item 7: The cost-benefit ratio justifies its implementation.

The content validity index (CVI) was calculated as the percentage of experts who rated each item 4 or 5 points. A CVI $\geq 90\%$ was considered valid. The durability of the material was assessed subjectively by the evaluators after they handled the simulator, without standardized stress tests. No reliability analyses, such as Cronbach's alpha or test-retest tests, were performed on the Likert scale, an aspect recognized as a limitation.

Phase 3: Student Evaluation

Thirty fourth-year medical students participated and were selected for convenience during their rotation in Neonatology, without a power calculation, since this was a pilot validation phase. The students received a 20-minute theoretical session on abdominal wall defects, which was delivered by the principal investigator and standardized using a script that included definitions, pathophysiology, and initial management protocol. They were subsequently introduced to the simulator and asked to perform a single sequence of initial management steps (protecting hernial rings with wet compresses, verifying the orogastric tube, and identifying the type of defect). Finally, they evaluated the simulator using the same instrument applied to the experts. No objective pre/post assessment of psychomotor skills was performed; the study was limited to perceptions of usefulness and self-efficacy.

The data were processed in Microsoft Excel 2016. For the descriptive statistics of the Likert scale responses, medians and interquartile ranges (IQRs) were calculated, given the ordinal nature of the data. Comparisons between expert and student ratings were performed using the Mann–Whitney U test for independent samples, with a p value < 0.05 considered to indicate statistical significance.

The study was approved by the Ethics Committee of the Faculty of Medicine No. 2. All participants (experts and students) signed informed consent forms. The anonymity and confidentiality of the data were guaranteed.

RESULTS

The 5 selected experts met the inclusion criteria (average score: 8.2 ± 1.3 points) and represented the following specialties: Neonatology (2), Pediatric Surgery (1), and Medical Education (2). (Table 1)

The experts suggested improving the texture of the intestinal loops (item 2) and reinforcing the connection points to increase durability (item 5). These observations were recorded even though the medians for these items fell into the high category.

Thirty students participated (63.3% female, mean age 23.4 ± 1.2 years). (Table 2).

Table 1. Expert validation results

Item	Median (IQR)	IVC (%)
1. Realism of the newborn	5 (4–5)	100
2. Realism of intestinal loops	5 (4–5)	80
3. Anatomical correction of the defect	5 (5–5)	100
4. Usefulness for initial management practice	5 (5–5)	100
5. Material strength	4 (4–5)	80
6. Educational value for undergraduates	5 (5–5)	100
7. Cost–benefit ratio	5 (5–5)	100
Overall IVC	94.2	

Source: Author's own calculations.

With respect to the perception of improvement in understanding (Table 3), 86.7% of the participants (26/30) reported that the simulator “greatly” or “quite a bit” improved their understanding of the initial management of these defects. These data reflect self-perceived learning, not an objective measurement of acquired competence.

When the evaluations of both groups were compared using the Mann–Whitney U test, no statistically significant differences were found for any of the seven items ($p > 0.05$), indicating that the students' assessments did not differ from those of the experts. (Table 4)

Table 2. Student assessment results

Item	Median (IQR)	IVC (%)
1. Realism of the newborn	4 (4–5)	93.3
2. Realism of intestinal loops	4 (4–5)	83.3
3. Anatomical correction of the defect	5 (4–5)	96.7
4. Usefulness for initial management practice	5 (5–5)	100
5. Material strength	4 (4–5)	76.7
6. Educational value in undergraduate programs	5 (5–5)	100
7. Cost–benefit ratio	5 (5–5)	100
Overall IVC	92.9	

Source: Author's own work.

Table 3. Perception of educational utility among the 30 students evaluated

Perception	n	%
"Greatly" improved their understanding	18	60.0
Their comprehension improved "quite a bit"	8	26.7
Their comprehension improved "moderately"	3	10.0
Their comprehension improved "slightly"	1	3.3
Did not improve their comprehension	0	0

Source: Author's own work.

Table 4. Comparisons between groups (Mann–Whitney U test)

Item	p value
1. Realism of the newborn	0.342
2. Realism of intestinal loops	0.451
3. Anatomical correction of the defect	0.287
4. Usefulness for initial management practice	0.156
5. Material strength	0.398
6. Educational value for undergraduate students	0.201
7. Cost–benefit ratio	0.178

Source: Author's own work.

DISCUSSION

This study describes the development and validation of a low-cost simulator for neonatal abdominal wall defects, specifically gastroschisis, adapted to the conditions and resources available in Cuba. The results show that it is feasible to construct functional educational models with minimal investment, achieving CBI scores above 90% among both experts and students.

These results are consistent with the WALL-GO study by Medeiros et al. (1), which reported costs of \$15–27 per simulator and an IVC rate exceeding 94%. The similarity in acceptance suggests that the principles of construction using low-cost materials are transferable across Latin American contexts, although differences in final cost depend on local prices and exchange rates. Other groups have developed gastroschisis models using 3D printing or silicone, resulting in higher costs (50–150 USD) but with advantages in terms of durability. (9–11) The present proposal stands out for its low monetary cost and immediate reproducibility without the need for advanced technologies.

The bibliometric analysis by Flores-Cohaila et al. (5) revealed that general surgery was the specialty with the highest output in cost-effectiveness studies (27% of the studies), followed by obstetrics and gynecology (14.5%). This study aligns with this trend by addressing a topic at the intersection of both specialties: the neonatal management of congenital defects.

The Cuban healthcare system, organized into integrated networks with a strong emphasis on primary care, requires that general practitioners and primary-level neonatologists safely stabilize these patients prior to transfer. (4) However, the low incidence of gastroschisis (approximately 11.6 per 10,000 births) and the concentration of definitive surgery in tertiary centers limit students' clinical exposure. (3,12-17) Low-cost simulation emerges as an educational solution to standardize training and ensure that all graduates acquire the fundamentals of initial management, regardless of their direct clinical experience. Low-cost simulation is emerging as a pedagogical solution that allows for the standardization of training and ensures that all graduates acquire basic competencies for initial management, regardless of their clinical exposure during undergraduate studies.

The present study has several limitations that must be considered. First, content validation was performed with a small sample of 5 experts; although authors such as Lynn (7) consider this adequate for initial phases, it limits generalizability. Second, the students' evaluation of the simulator was based exclusively on self-perceived learning, without an objective measure of performance, such as checklists or an Objective Structured Clinical Examination (OSCE). Third, long-term skill retention was not assessed, nor were reliability tests conducted for the Likert scale used (Cronbach's alpha, test-retest). Fourth, the study was a single-center study, which limits its external validity. Fifth, the CCI scores for the items on the realism of intestinal loops and material strength were less than 90%, indicating specific areas for improvement. Sixth, material strength was assessed only subjectively, without stress tests to determine the exact number of uses before deterioration. Finally, the comparative statistical analysis allows us to state only that no significant differences were detected between groups and that "concordance" was not detected in a clinical or psychometric sense.

Therefore, caution is needed when extrapolating the results. The positive perception of 86.7% of the students should not be interpreted as evidence of clinical competence but rather as an indicator of acceptability and perceived self-efficacy. Future research should incorporate objective assessments (OSCE), a multicenter design, controlled durability tests, and cost-effectiveness analyses to compare this model with traditional teaching. Furthermore, it would be desirable to validate an assessment instrument with robust psychometric properties and to evaluate skill retention at 3 and 6 months.

Nevertheless, the developed simulator can be integrated into simulation workshops in the specialties of Pediatrics and Neonatology, in training for general practitioners joining rural services, and in continuing education programs for nursing staff and neonates.

CONCLUSIONS

A low-cost simulator for gastroschisis was successfully developed using local materials, achieving a content validity index of more than 90% and a material cost of 1,950 CUP (3.93 USD), which are significantly lower than those of commercial simulators. Expert and student evaluations agreed that the model is useful for teaching initial management. Given its economic feasibility and relevance to the Cuban regionalized health system, its progressive incorporation into undergraduate simulation workshops and continuing education for primary care personnel is recommended. Extending validation with objective performance measurements and across multiple centers will consolidate the educational impact of this tool in the chain of survival for newborns with gastroschisis.

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