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Novel indigenous low cost (NICA) model for hands on training of surgical interns in incision and drainage procedure for superficial skin abscess

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Abstract

Background Surgical education necessitates hands-on training, which poses ethical challenges when practicing on real patients. Simulation training emerges as a pivotal solution, offering a safe and effective environment for skill acquisition. However, existing simulation models often overlook common surgical conditions like superficial skin abscesses. The National Medical Commission advocates for simulation-based training in basic surgical skills, highlighting the need for accessible and cost-effective models. Thus, this study aimed to develop and evaluate a novel Indigenous Cost-effective model for Incision & Drainage (NICA) of subcutaneous abscesses, addressing the gap in surgical education.

Methodology Following institutional ethics clearance, the study employed Kern's Six-step approach for curriculum development. The NICA model was conceptualized and crafted using locally available, low-cost materials, validated by expert opinion, and implemented in a simulation lab setting. A total of 155 surgical interns underwent training, consisting of didactic video sessions, hands-on practice with the NICA model, and structured assessments. Pre- and post-training evaluations were conducted to measure interns' performance and feedback.

Results Expert validation confirmed NICA model's fidelity and usefulness. Training 155 surgical interns resulted in significant skill improvements. Pre-training, 33% correctly performed pre-procedural requisites, 46% executed procedural techniques, and 48% performed post-procedural steps accurately. Post-training, these percentages surged to 95%, 97%, and 98%, respectively. Post test score showed significant skill enhancements across all domains ($p < 0.05$). Intern feedback highlighted increased confidence, satisfaction, and interest in learning, affirming NICA model's effectiveness.

Conclusion The development and implementation of the NICA model offer a scalable and cost-effective solution for surgical training in resource-limited settings. The model's effectiveness in enhancing interns' skills and confidence underscores its potential to address training needs effectively. The study highlights the significance of simulation-

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based training in surgical education and advocates for the widespread adoption of indigenous low-cost models to improve surgical skills acquisition.

Keywords Surgical education, Simulation training, Curriculum development, Medical education

Background

Surgical education unlike other fields in medicine needs hands on training for teaching the surgical skills. The best way to learn and hone the surgical skills is by getting trained in real surgical setup and real patients. But ethically it is not permissible for novice learners perform in real patients. Hence it is evident that simulation plays a vital role in training in surgical skills [1]. In simulation training, the medical students are provided training in replicated or recreated clinical setup [2, 3]. Simulation models in surgery vary from animal models, cadaveric models, synthetic models, virtual reality and augmented reality models [4]. Simulation is more widely used in high income countries and the simulation models that are available in these countries are either for basic suturing and knotting techniques or advance laparoscopic techniques [5]. The actual need of simulation is for demonstrating clinical signs of common surgical conditions like abscess, lipoma like subcutaneous swelling, inguinal hernia, hydrocele and for basic surgical procedures like abscess drainage, excision of subcutaneous swellings, hernia repair and hydrocele surgery.

The National Medical Commission strongly recommends use of simulation models for teaching basic surgical skills for undergraduate medical students in the Competency based medical education [6]. Superficial skin abscess is one of the most common surgical conditions seen in the clinical practice. Every medical graduate should be confident diagnosing this surgical condition. Incision and drainage under local anesthesia is the surgical procedure warranted for abscess and it can be done as an out-patient procedure if they have the surgical expertise. National Medical Commission has made mandatory that all medical interns should be trained in incision and drainage of abscess in a simulation model [7]. It is a certifiable skill in Competency based medical education. A previous study introduced a novel, high-fidelity simulation phantom for training in ultrasound-guided identification and drainage of superficial soft tissue abscesses. The model, constructed from precooked polenta and paintballs, offered a quick-to-prepare, reusable, and easily reproducible alternative for medical education in point-of-care ultrasonography and procedural skills [8]. Recently, another study presented the development of a novel, easily replicable model for training in ultrasound-guided identification, aspiration, and incision & drainage of superficial abscesses. The model, made from commercially available materials, offered an affordable alternative for medical education, allowing students to gain hands-on experience in these essential clinical skills [9]. Currently there is no readily available low-cost model for Incision and Drainage of abscess in India.

Developing a cost-effective indigenous scalable simulation model using locally available materials for surgical training of incision and drainage (I&D) of subcutaneous abscesses will result in comparable training outcomes to traditional training methods, while reducing costs and improving accessibility to training. This model for training on Incision and Drainage of subcutaneous abscess can address the following domains within healthcare: to teach technical and procedural skills and to assess performance of clinical procedural skills. Hence the aim of the study was to develop a cost-effective indigenous simulation model for surgical training of I & D of subcutaneous abscess that is accessible, realistic, and effective in improving interns' skill and performance.

Objectives

i. To design and develop low-cost indigenous simulation model (NICA) for hands on training in Incision and Drainage of subcutaneous abscess.
ii. To validate the NICA model by Expert Opinion.
iii. To evaluate the effectiveness of NICA model in improving the trainee performance.

Methodology

This study encompasses a meticulous journey of conceptualization, design, implementation, and evaluation of NICA (Novel Indigenous Cost-effective model of Incision & drainage of subcutaneous Abscess) model. Institutional Ethics Clearance was obtained from SRIHER (DU) (IEC-NI/22/APR/82/38). Informed consent was obtained from all the participants.

The study was conducted based on 'Curriculum Development for Medical Education: A Six Step Approach' by David Kern (Suppl. Figure: S1) [10].

Design and development of the NICA model

This novel indigenous model is made of very low cost materials like synthetic sponge, thin brown colour rexine sheet, water, all-purpose flour/toothpaste, yellow colour, unsterile gloves and glue. Thick yellow colored fluid was prepared mixing all purpose flour/toothpaste with yellow colour and water. One glove finger was filled with 5 ml of this fluid and the glove was tied with thread forming a small ball. This was stuck to a 5*5 cm sponge-sheet and

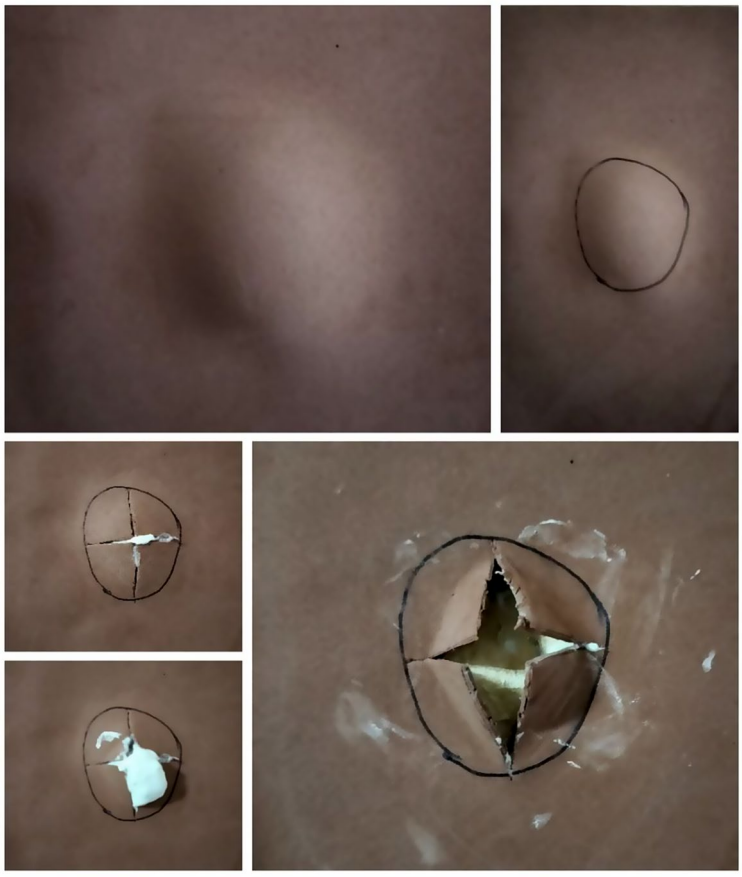

Fig. 1 NICA MODEL for Incision & Drainage of Subcutaneous Abscess

Fig. 2 The NICA model placed on Lower and Upper limb task trainer

thin brown foam sheet was stuck over this. In this manner superficial skin abscess model was developed. The cost of preparing one kit is around rupees 10. The clinical signs of acute inflammation, fluctuation sign (seen in cystic swellings) could be clearly demonstrated with this model. Incision & drainage of abscess was demonstrated to medical students and interns and hands on training for the same could be provided (Fig. 1).

This model can be made as a hybrid model by anchoring it to an existing task trainer (Fig. 2) available in the teaching Institute or it can be placed on a human volunteer or standardised patient, which will mimic real life situation.

Validation by the experts Simulation clinical scenarios were created. Checklist for steps in training and assessing the surgical interns in Incision and Drainage of subcutaneous abscess was developed. The validation of the NICA model involved a comprehensive evaluation by nine surgical experts.

(with minimum of five years of experience). Each expert performed incision and drainage procedures on the model, followed by an assessment of its physical, functional, and psychological fidelity, as well as its overall usefulness. The experts rated these aspects on a scale from "Strongly Disagree" to "Strongly Agree," and provided overall fidelity and usefulness scores on a scale

of 1 to 5. This multi-dimensional assessment approach allowed for a thorough evaluation of the model's effectiveness as a surgical training tool.

Implementation After getting informed consent, 155 willing interns with 6 months of training were enrolled in the training. The training was done in the simulation lab in the department of general surgery. Each session lasted for 8 h and constituted 10 interns. The training was done by the same senior surgeon for all the enrolled interns. Each intern was trained in the basic surgical skill of Incision and Drainage of subcutaneous abscess. Feedback was obtained from the trained interns about the model (Suppl. Figure S2).

Before the training using the NICA model, all the enrolled interns were instructed to watch the surgical video of the Abscess Incision & drainage procedure the previous day. Then each intern performed I & D procedure which was observed and assessed using the checklist of structured surgical skills assessment tool. Then the same skills were demonstrated by the senior surgeon in a systematic step by step manner using the NICA model. After the demonstration each intern performed the skills which were observed and corrected individually by the surgeons. At the end of the training each intern performed I & D procedure which was observed and assessed using the checklist of structured surgical skills assessment tool.

Interns provided feedback on 5 domains, confidence, satisfaction, attitude, fidelity and usefulness of the NICA model. The skills were grouped as pre procedural, procedural skills and post procedural skills. Pre procedural skills included Mark the Abscess/Incision, Loading the local anaesthetic drug Administering, Local anesthesia, Selecting the appropriate blade and Selecting the appropriate handle, Procedural skills included Holding the instrument, Angle of blade to skin during incision, Depth of incision, Length of incision and draining of pus and Post procedural skills included Mopping, Packing and Dressing. The assessment scores were calculated based on the structured surgical skills assessment tool. All the results were tabulated and analysed.

Statistical analysis The data were analysed using R statistical software version 4.0.2. Continuous variables are expressed as mean ± standard deviation (SD), while categorical variables are presented as frequencies and percentages. Student's t-test and proportion test were employed to compare outcomes before and after simulation for continuous and categorical variables, respectively. Additionally, effect size estimation, such as Cohen's d, was computed to quantify the magnitude of differences after the simulation. P-value < 0.05 was considered statistically significant.

Results

The study on the indigenous low-cost NICA model for hands-on training of surgical interns in incision and drainage procedures for superficial skin abscesses yielded promising results, demonstrating the efficacy and feasibility of the training intervention. NICA scalable prototype simulation model was designed using suitable low-cost materials which was validated by the experts and tested for its effectiveness in simulating the I & D procedure and improving the trainee performance.

Validation of NICA model

Each expert performed incision and drainage procedures on the model, followed by an assessment of its physical, functional, and psychological fidelity, as well as its overall usefulness. The results showed that for physical fidelity, five experts agreed and four strongly agreed. For functional fidelity, six agreed and three strongly agreed. Regarding psychological fidelity, seven agreed and two strongly agreed. For usefulness, eight agreed and one strongly agreed. The median rating for both fidelity and usefulness was 4 out of 5 (Suppl.Table:S1).

Evaluation of effectiveness of NICA model

155 surgical interns were given hands on training for I and D of subcutaneous abscess in the NICA model and their performance was assessed using structured skill assessment tool.

After watching the Incision & Drainage surgery video and before the structured training using the NICA model 33% of interns were able to perform the pre procedure requisites correctly and 46% of interns were able to perform the procedural technique of I & D correctly and 48% of interns were able to perform steps in mopping and packing correctly. After the structured training using the NICA model 95% of interns for able to perform the pre procedure requisites correctly and 97% of interns were able to perform the procedural technique of I & D correctly and 98% of interns were able to perform steps in mopping and packing correctly as shown in Fig. 3. The improvement in the performance was statistically significant.

The scores for the all the skills computed using the structured surgical assessment tool was compared before and after training them with the NICA simulation model (Table:1). The scores were higher after the training with NICA simulation model which was statistically significant with significant effect size estimates (Fig. 4; Table 2).

Analysis of the feedback by the interns

In the Domain of Confidence, 93% of interns strongly agreed that their confidence in performing incision & drainage improved by this training, 95% strongly agreed that their confidence in administrating local anaesthesia

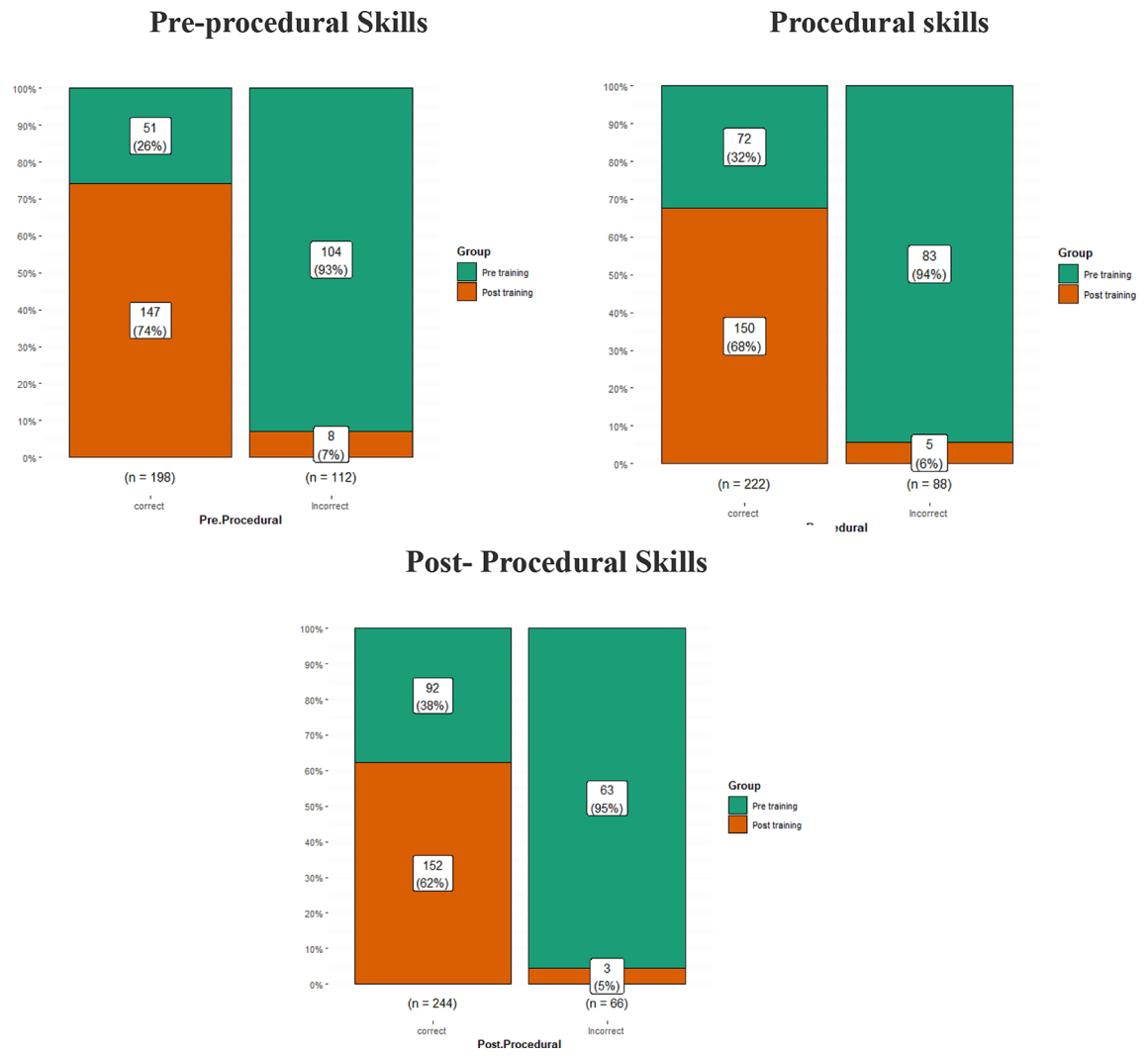

Fig. 3 Improvement in the I & D of subcutaneous abscess performance of the interns before and after training using NICA Model

improved 97% of interns strongly agreed that this structured training using the NICA model improved their knowledge and clinical skills. In the Domain of Attitude, 95% of interns strongly agreed that the training met their requirement of knowledge and skills, 97% of interns strongly agree that this training kindled their interest in learning, 100% of interns said that they were interested in attending similar sessions in future and 100% of interns said that they would recommend this training to their juniors and friends. On the Domain on the Usefulness and Fidelity of the NICA (Fig. 5) model 91% of interns strongly agreed that the training resembled real life situation, 92% of interns strongly agreed the visual aspect was realistic, 92% of interns strongly agreed that haptics was realistic, 92% of interns strongly agreed that incising the skin was realistic, 91% of interns strongly agreed that performing incision and drainage in the model was realistic, 94% of interns agreed that moping and packing was realistic and 93% of interns rated the training capacity of the model as 5 in the rating scale of 1 to 5 where five is the maximum, 94% of interns rated the Usefulness & Fidelity of the model as 5 and remaining 6% of interns rated as 4.

Following the training using NICA simulation model, surgical interns exhibited significant improvements in pre procedural, procedural and post-procedural skills related to incision and drainage procedures. Pre- and post-training assessments revealed a statistically significant increase in interns' understanding of abscess pathophysiology, procedural steps, and infection control protocols. Objective structured assessment of the skills demonstrated a notable enhancement in interns' ability to perform incision and drainage procedures accurately and efficiently. The result of this study highlights the NICA simulation model's effectiveness based on trainee performance, satisfaction, and cost-effectiveness.

Table 1 I & D of subcutaneous abscess performance of the interns before and after training using NICA Model

Variables	Factors	Details	Pre Training	Post Training	*P* value
Pre Procedural	Mark the Abscess/Incision	Correct	48(26)	134 (74)	< 0.01
		In correct	107(84)	21(16)	< 0.01
	Loading the local anesthetic drug	Correct	60(29)	145(71)	< 0.05
		In correct	95(90)	10(10)	< 0.01
	Administering Local anesthesia	Correct	36(19)	151(81)	< 0.01
		In correct	119(97)	4(3)	< 0.05
	Selecting the appropriate blade	Correct	40(21)	155(79)	< 0.01
		In correct	115(100)	0	NA
	Selecting the appropriate handle	Correct	68(31)	148(69)	< 0.01
		In correct	87(93)	7(7)	< 0.01
Procedural	Holding the instrument	Correct	56(27)	154(73)	< 0.05
		In correct	99(99)	1(1)	< 0.05
	Angle of blade to skin during incision	Correct	83(35)	153(65)	< 0.01
		In correct	72(97)	2(3)	< 0.01
	Depth of incision	Correct	67(32)	140(68)	< 0.05
		In correct	88(85)	15(15)	< 0.05
	Length of incision	Correct	56(27)	154(73)	< 0.01
		In correct	99(99)	1(1)	< 0.01
	Draining of pus	Correct	98(40)	150(60)	< 0.05
		In correct	57(92)	5(8)	< 0.01
Post Procedural	Mopping	Correct	74(33)	152(67)	< 0.01
		In correct	81(96)	3(4)	< 0.01
	Packing	Correct	101 (40)	149(60)	< 0.01
		In correct	54 (90)	6 (10)	0.01
	Dressing	Correct	101 (39)	155(61)	< 0.01
		In correct	54(100)	0	NA

Discussion

This study has provided the steps in developing a scalable indigenous simulation model designed and prepared using locally available cost-effective material which will be useful for training large group of students in resource limited settings. Through empirical evidence this study has highlighted the potential impact of NICA model on honing the surgical skills of interns. Qualitative feedback from participants indicated high levels of satisfaction with the training intervention using indigenous low-cost NICA model. Experts appreciated the realistic simulation provided by the model, as well as its affordability, accessibility, and relevance to medical education. The study highlighted the sustainability and scalability of the indigenous low-cost model, emphasizing its potential to address training needs in resource-limited settings. The use of locally available materials and simple construction techniques will facilitate the widespread adoption and implementation of this model.

The indigenous low-cost model is more effective than the traditional training methods, such as didactic lectures or observation-based learning. The hands-on approach facilitated by the model offered a more immersive and engaging learning experience, leading to better retention of knowledge and skills among interns.

Mastering the basic surgical skills is a pivotal part of training all doctors. It has been recommended that these basic skills training should be in controlled manner in a simulated environment initially and only after the interns are confident, they can do these procedures on patients [11]. Training the novice doctors in simulation models helps to improve their psychomotor skills and it also enhances and hones their performance in other complex surgical skills [12]. According to literature, Simulation models are classified as low fidelity and high fidelity models [13, 14]. It has been long believed that 'surgical skills have to be taught in a more realistic environment [15, 16] but many studies have shown through their objective method of assessment that novice surgical residents learn surgical skills when given systematic hands on training regardless of whether the simulation/skill model is of low or high fidelity [17, 18]. The studies also showed that acquisition of surgical skills is not based on the fidelity of the training model [19, 20]. So when planning a teaching schedule for surgical skills, the training model should not be decided only on the basis of fidelity. Factors like ease of production, cost, portability, need for software/electricity, ease of transportation, usage in low-resource institutions, all there should also be considered [21, 22]. There have been many studies on the need for low-cost stimulation models for training in surgical skills [23]. There are many simulation models for laparoscopic training, there aren't many established models for basic surgical skills of incision and drainage of subcutaneous abscess. This surgical skill is a certifiable skill in the current CBME recommended by NMC. The NICA model developed is for training novice surgical residents in this skill. It is a novel indigenous low-cost simulation model for training for surgical residents in I & D of subcutaneous abscess.

Allen J has reported that simulation models are classified as low or high Fidelity based on three domains on which they are assessed [24].

i. Model - how the model appears otherwise known as Physical fidelity.

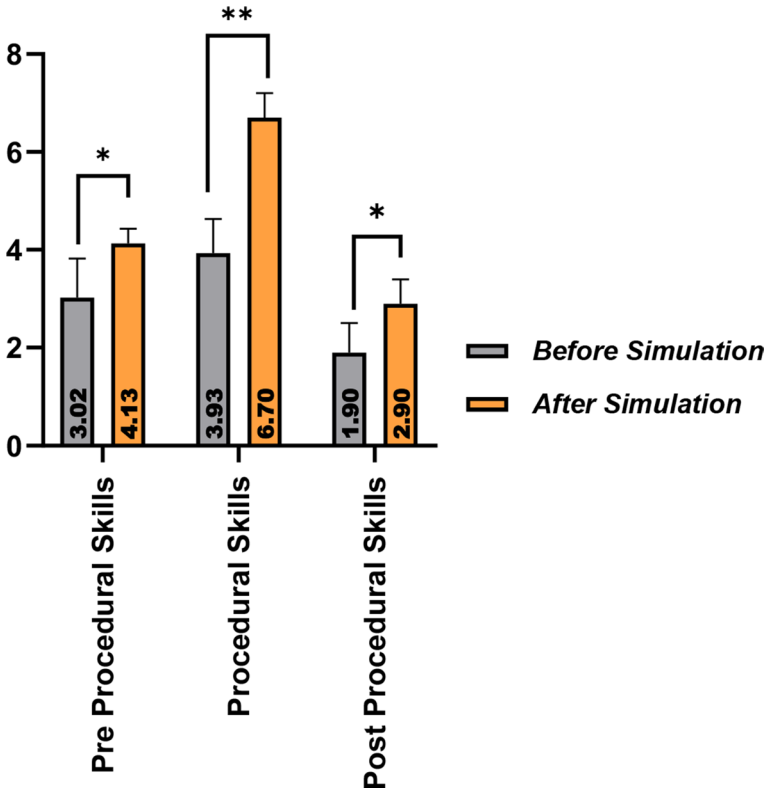

Fig. 4 Improvement in the I & D skill Scores before and after training using NICA simulation Model

Table 2 I & D skill scores and effect size estimates before and after training using NICA simulation model

Variables	Before Simulation	After Simulation	*P* value/ Effect size (d)
Pre Procedural skills	3.02 (0.88)	4.13 (0.34	0.01/1.02
Procedural skills	3. 93 (0.79	6.70 (0.56)	0.001/2.4
Post Procedural skills	1.92 (0.68)	2.90 (0.20)	0.01/1.52

ii. Equipment - what the model does otherwise known as Functional fidelity whether the trainees feel confident.
iii. Psychological - how the model is perceived, that is their attitude towards or about the model.

In the feedback form obtained, when we assessed the physical fidelity, both the surgical experts and the training interns strongly agreed that the NICA model was realistic and its visual aspect and haptics were realistic. For the Functional fidelity, in the feedback form the surgical interns after the training with the NICA model reported higher confidence level in their Incision and Drainage surgical skills. The surgical experts also opined in their feedback that training with this kind of model will improve the technical procedural skills of the students. For the Psychological fidelity, when the surgical interns were asked to rate the model, they gave highest score of 5 and when the surgical expert were asked to rate about the usefulness and fidelity of the model, their rating was between 4 and 5 out of a score of 5. Both of the feedback indicated that the Psychological fidelity of the model was also high. The interns also suggested that similar models could be developed for other basic surgical skills such as Excision of subcutaneous swelling.

Indigenous models can be easily customized or adapted to accommodate specific training needs. This NICA model can be placed on an existing task trainer (like upper limb or lower limb or an abdominal model) in the teaching Institute or on a standardised patient. Simulation scenarios can be prepared, wherein the students can elicit history from the standardized patient, practice obtaining informed consent for the procedure from the standardized patient. Then they can do clinical examination on the model and have hands on training for Incision and drainage of subcutaneous abscess on the NICA model. All the above can also be assessed using the checklist. Thus, this model can be used for both training the students as well as for assessing the students. The model can also be used for Complex team building scenarios. Having a consistent and standardized training model ensures that all interns receive uniform instruction and practice, promoting quality assurance and patient safety in incision and drainage procedures.

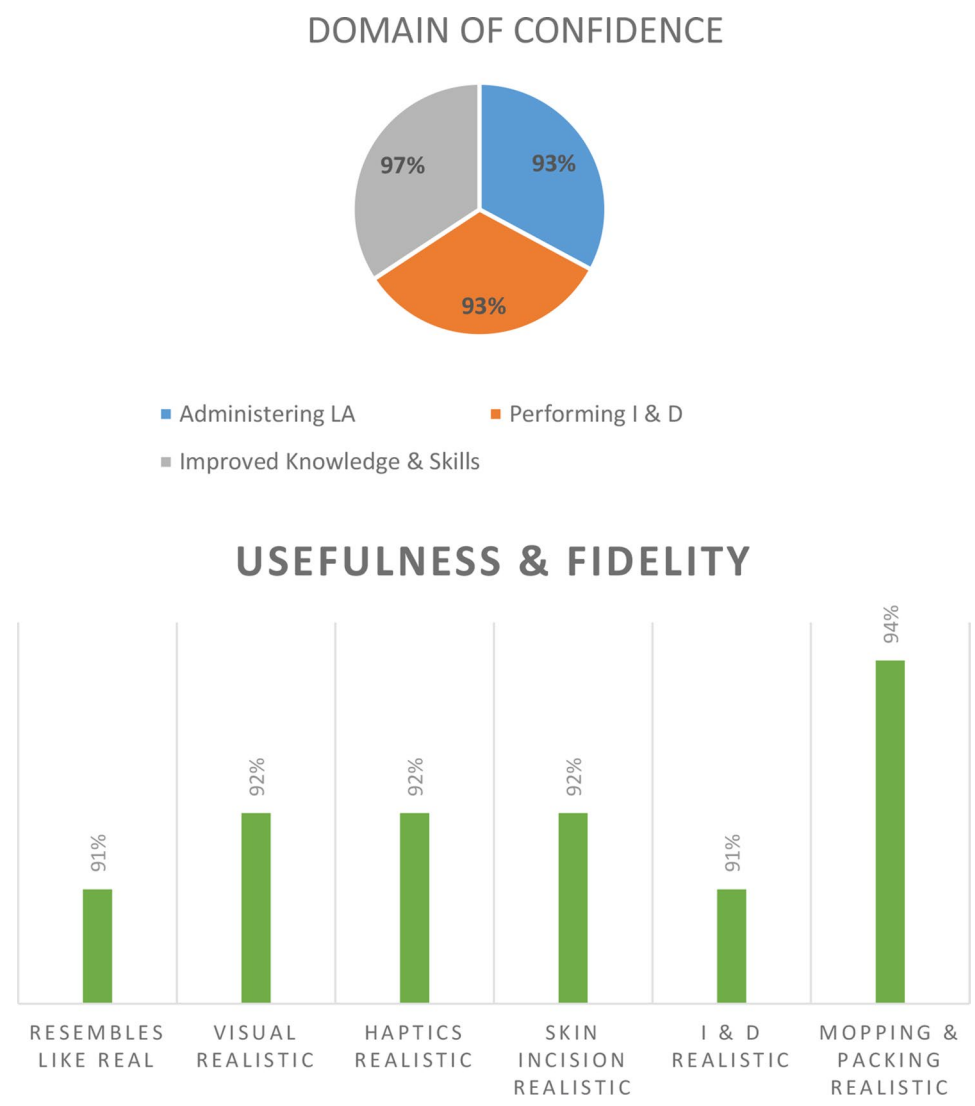

Fig. 5 Feedback regarding NICA model by the Interns

This NICA model, can be made using locally available low-cost materials. The cost of making one kit is less than 10 rupees and within 10 min, 10 NICA model kits can be prepared simultaneously. These simulation models can address three domains within healthcare:

1. To teach technical/ procedural skills to a large number of students.
2. To assess performance of clinical skills in a large number of students.
3. To help in complex team training scenarios.

The highlights of this model will be simplicity of production, low cost, portability, easy reproducibility, scalability and hands-on training. This model does not require of any advanced hardware/software modules and electricity. It will serve as a prototype which can be replicated by others. These models can be archived for subsequent batches of students, and the scientific information and evidence generated in this study will help medical educators to adapt different simulation-based teaching-learning strategies for the current Competency based Medical curriculum rolled out by the National Medical Commission. Similar to this model, low cost models can be created for other basic surgical conditions also.

The study would emphasize how the use of locally available materials and simple construction techniques enables widespread adoption and implementation of the training methods, addressing critical training needs without imposing significant financial burdens on medical institutions.

Conclusion

In conclusion, the results of the study support the effectiveness and practicality of utilizing an indigenous, scalable, low-cost NICA model for hands-on training of

surgical interns in incision and drainage procedures for superficial skin abscesses which is a certifiable skill in the competency based educaiton. By enhancing interns' knowledge, skills, and confidence levels, the training intervention has the potential to improve patient outcomes and strengthen healthcare delivery in diverse clinical settings. Further research and refinement of the model are warranted to optimize its impact and ensure its continued relevance in surgical education.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12909-024-06013-w.

Supplementary Material 1

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Author contributions
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Data availability
The datasets analysed in the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Institutional Ethics approval was obtained from SRIHER (DU) (IEC-NI/22/APR/82/38). Informed consent was obtained from all subjects prior to data collection.

Consent for publication
Not applicable. The manuscript and images do not contain any individual person's identifiable data.

Competing interests
The authors declare no competing interests.

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References

1. Teodor PG, Vanessa NP. Simulation in surgical education. Can Med Assoc J. 2010;182(11):1191.
2. Dawe SR, Pena GN, Windsor JA, Broeders JA, Cregan PC, Hewett PJ, et al. Systematic review of skills transfer after surgical simulation-based training. Br J Surg. 2014;101(9):1063–76.
3. Owen H. Early use of simulation in medical education. Simul Healthc. 2012;7(2):102–16.
4. Badash I, Burtt K, Solorzano CA, Carey JN. Innovations in surgery simulation: a review of past, current and future techniques. Ann Transl Med. 2016;4(23):453.
5. Lahanas V, Georgiou E, Loukas C. Surgical simulation training systems: box trainers, virtual reality and augmented. Int J Adv Robot Automn. 2016;1(2):1–9.
6. Gupta SK, Srivastava T. Assessment in undergraduate competency-based medical education: a systematic review. Cureus. 2024;16(4).e58073
7. Nicka A, Swanson-Biearman B. Development of a subcutaneous abscess simulator for incision and drainage. Clin Simul Nurs. 2019;37:40–3.
8. Augenstein JA, Yoshida H, Lo MD, Solari PA, Readily Available. Inexpensive, and reusable simulation model for teaching ultrasound-guided abscess identification and drainage. J Emerg Med. 2016;50(3):462-5. https://doi.org/10.1016/j.jemermed.2015.12.020. PMID: 26899194.
9. Ladowski JM, Kang L, Triplett L, Fogler B, Migaly J, Zani S, Jackson L, Vatsaas CJ. A novel low-cost model of superficial abscess for trainee education in incision and drainage. Surg Open Sci. 2023;14:124–7.
10. Kern DE. A six-step approach to curriculum development. InCurriculum development for medical education a six-step approach 2009 (pp. 5–9). Baltimore: Johns Hopkins University.
11. Singh DR, Regmee S, Chakradhar R, Agrawal A, Bhujel K, Gurung S, Laudari U, Bohara TP. Role of surgical simulation to enhance the knowledge of surgical procedures. J Soc Surg Nepal. 2020;23(2):14–7.
12. Sanfey H, Dunnington G. Verification of proficiency: a prerequisite for clinical experience. Surg Clin North Am. 2010;90(3):559–67.
13. Sharma D, Agrawal V, Bajajb J, Agarwala P. Low-cost simulation systems for surgical training: a narrative. J Surg Simul. 2020;5:1–20.
14. Hammoud MM, Nuthalapaty FS, Goepfert AR, Casey PM, Emmons S, Espey EL, Kaczmarczyk JM, Katz NT, Neutens JJ, Peskin EG. Association of professors of gynecology and obstetrics undergraduate medical education committee. To the point: medical education review of the role of simulators in surgical training. Am J Obstet Gynecol. 2008;199(4):338–43.
15. Reznick RK. Teaching and testing technical skills. Am J Surg. 1993;165(3):358–61.
16. Van Hove PD, Tuijthof GJ, Verdaasdonk EG, Stassen LP, Dankelman J. Objective assessment of technical surgical skills. Br J Surg. 2010;97(7):972–87.
17. Denadai R, Oshiiwa M, Saad-Hossne R. Does bench model fidelity interfere in the acquisition of suture skills by novice medical students? Rev Assoc Med Bras. 2012;58(5):600–6.
18. Denadai R, Saad-Hossne R, Oshiiwa M, Bastos EM. Training on synthetic ethylene-vinyl acetate bench model allows novice medical students to acquire suture skills. Acta Cir Bras. 2012;27(3):271–8.
19. Anastakis DJ, Regehr G, Reznick RK, Cusimano M, Murnaghan J, Brown M, et al. Assessment of technical skills transfer from the bench training model to the human model. Am J Surg. 1999;177(2):167–70.
20. Grober ED, Hamstra SJ, Wanzel KR, Reznick RK, Matsumoto ED, Sidhu RS, et al. The educational impact of bench model fidelity on the acquisition of technical skill: the use of clinically relevant outcome measures. Ann Surg. 2004;240(2):374–81.
21. Denadai R, Souto LR. Organic bench model to complement the teaching and learning on basic surgical skills. Acta Cir Bras. 2012;27(1):88–94.
22. Denadai R, Kirylko L. Teaching basic plastic surgical skills on an alternative synthetic bench model. Aesthet Surg J. 2013;33(3):458–61.
23. Denadai R, Saad-Hossne R, Todelo Andréia, Kirylko L, Souto LuísR. (2014). Low-fidelity bench models for basic surgical skills training during undergraduate medical education. Rev Col Bras Cir. 2014 Mar-Apr;41(2):137 – 45. English, Portuguese. https://doi.org/10.1590/s0100-69912014000200012. PMID: 24918729.

24. Allen J, Bufardi L, Hays R. The relationship of simulator fidelity to task and performance variables. Report no. ARI-91-58. 1991. Alexandria: Army Research Institute for the Behavioural and Social Sciences; 1991.

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