WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.084
Volume 8, Issue 11, 1399-1406. Review Article ISSN 2277– 7105

INNOVATIONS IN EXPERIMENTAL SURGICAL MODELS

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Article Received on 19 August 2019,
Revised on 09 Sept. 2019,
Accepted on 29 Sept. 2019,
DOI: 10.20959/wjpr201911-15974

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ABSTRACT

Experimental models provide surgical training and skills practice by doing it repeatedly and ensure that trainees have some experience before treating humans. It avoids the use of patients. Attainment of surgical competence requires a good balance between knowledge, surgical skill, judgment and professionalism. *Sushruta* has rightly said that even after learning all the scriptures in depth, a surgeon cannot treat his patients accurately without fear if he has not mastered surgical skills by practicing it repeatedly. To deal this condition, *Sushruta* has dedicated one chapter on "how to train surgeon by using experimental models without involving human beings". These experimental models involved parts of plants and animals at that time. From that time till today, we have progressed and many experimental models have been designed to train medical students like live animals, cadavers, bench top models, and virtual reality simulators. This article is devoted to these experimental models right from past techniques, to the current technology and to future innovations.

KEYWORDS: *Yogya*, Experimental surgical models, Simulator.

INTRODUCTION

In 1000 B.C., while describing the qualities of a surgeon, *Sushruta* has said, he should have enough confidence to perform surgical procedures, he should be prompt, fast acting, he must not be frightened, hopeless, and his hands must not have tremors due to fear.[1] To perform these surgical procedures promptly, adequately, confidently and without fear, he also has put emphasis on practical training of surgeons. That is very well mentioned in *Yogyavidhi*

Adhyaya[2] of *Sushruta Samhita*, describing use of various parts of plants, animals and wooden models to practice surgical procedures. He has also defined procedures to preserve a dead body and dissection of body to learn anatomy in *Sharira Sthana*.[3] In 600 B.C. in India, use of leaf and clay models to conceptualize nasal reconstruction with a forehead flap has also been mentioned.[4]

The next great advancement in experimental models or simulation occurred after 1980s. The first computerized patient simulator was CASE (Comprehensive Anesthesia Simulation Environment) for anesthesia training.[5]

The next innovation was introduction of VR simulation in 1990s. The first VR simulators included a virtual Achilles' tendon repair, cholecystectomy, wound debridement and suturing.[6] These computer based systems are safe for practicing surgery repeatedly and have no ethical issues.

MATERIAL AND METHOD

Collection of data was done mainly from *Sushruta Samhita* and relevant articles from internet. PUBMED database was searched with keyword Simulation and experimental models in surgery. Relevant articles were included for review.

Many platforms are increasingly used in surgical training programs for the learning and assessment of surgical skills. E.g. live animals, cadavers, bench-top models, virtual reality (VR) simulators and 3D-prototyping.

Low fidelity and high fidelity surgical models[7]: Surgical simulation models can be low-fidelity or high-fidelity, reflecting the closeness of the model to reality. Low-fidelity models are required to practice individual and basic surgical skills and techniques like hand-eye coordination and knot-tying. High-fidelity models are made to practice wide variety of skills and possess a high degree of realism to replicate an entire surgery.

PAST TECHNIQUES OF PRACTICING SURGICAL PROCEDURES

In "*Yogyasutriya Adhyaya*", *Sushruta* has explained how to practice various surgical procedures on various plants and animals to make one fit before going for real medical field.[8]

1. *Chhedana Karma* (Excision) - Different excision techniques should be practiced by making cuts on objects like *Pushpaphala* (A kind of gourd) *Alabu*, *Kalindaka* (Watermelon), *Trapusa* (Cucumber), *Ervaruka*.
2. *Bhedana Karma* (Incision and exploration) - Incision should be practiced on a leather bag, urinary bladder or leathern pot containing full of water and slime.
3. *Lekhana Karma* (Scrapping and scooping) - Lekhana *Karma* should be practiced on piece of hairy skin.
4. *Vedhana Karma* (puncturing) – In this procedure, superficial veins are pierced i.e. It should be taught on vein of dead animal or with help of lotus stem.
5. *Eshana Karma* (probing) – It should be practiced on worm eaten wood or on reed of bamboo or on mouth of dried gourd.
6. *Aharana Karma* (extraction) –Extraction should be learned by withdrawing seeds from the kernel of *bimbi*, *bilwa* or jack fruit. Extraction of teeth should be practiced from the jaws of dead animal.
7. *Vistravana Karma* (drainage) – Secreting or evacuating should be taught on surface of *shalmali* plant covered with bees wax.
8. *Seewana Karma* (suturing) – Suturing should be taught on pieces of cloths and skin,
9. *Bandha* (bandaging) - Bandaging should be demonstrated on specific limbs of full sized dummies made with stuffed linen.
10. *Agni Karma* (thermal cautery) and Kshar *Karma* (alkaline therapy) – Cauterizing or applying alkaline preparation should be taught on soft flesh pieces.
11. *Karna sandhi bandha* –Plastic surgery of ear should be demonstrated on soft muscle or stem of lotus.
12. *Netrapranidhan, Basti* (enema), *Vrana Basti* (wound cleaning/irrigation) – The art of inserting syringes; enema should be practiced by inserting tube into lateral fissure of a pitcher full of water or into mouth of gourd.

CURRENT EXPERIMENTAL MODELS IN SURGERY

1. **Live animals[9]:** Operations on anesthetized live animals are an effective and high fidelity tool for learning operative procedures, because both animal and human have many common features. It helps a surgeon to not only practice surgical procedure but also ways of avoiding complications and management of complications if they arise. It also has some drawbacks like ethical issues of using an animal as well as difference in structural anatomy of animal and human beings.

2. **Cadaver:** A cadaver is a dead human body that is used by medical students, physicians and other scientists to study anatomy, identify disease sites, determine causes of death, and provide tissue to repair a defect in a living human being. Fresh cadaveric tissue is the gold standard for surgical simulation because of its approximation to living tissue.[10] But being a dead tissue, it cannot faithfully replicate all physiological conditions that are encountered in operation theatre. *Sushruta* has also mentioned dissection of dead body and procedures to preserve it for anatomical study purposes in chapter five of *ShariraSthana*.

3. **Bench top models[11]:** They are both low fidelity and high fidelity models. Low fidelity models allows trainee to practice knot tying and suturing only. Hence they only allow practicing basic surgical skill. But high fidelity models are made up of both synthetic material and animal parts. It allows a resident to learn surgical procedures as well as assessment of technical performance. These complex models have been designed to replicate and train complete operations like aneurysm repair, joint replacement and fracture fixation. These high fidelity models are expensive, not readily available and provide less degree of realism. Practicing multiple times on these models makes a resident skillful and confident enough to perform procedure on human beings.

4. **Laparoscopic box simulators:** They are developed to practice minimally invasive surgeries. It allows resident to operate in a closed environment. It contains camera allowing resident to visualize their hand movements. Laparoscopic tasks like cutting, suturing, placing a ligating loop can be practiced by these simulators.[12] These models are very expensive and not easily available.

5. **Virtual reality (VR) simulators:** A surgery simulator is computer technology that captures minute anatomical details with high accuracy, thus creating realistic environment. These high fidelity simulators helps user to acquire good hand eye coordination, fine motor skills and familiarity of procedures.[13]

Training by virtual-reality simulation encompasses systems designed to teach laparoscopic, endoscopic and percutaneous interventions.[14] Unlike bench-model learning, the presence of an expert is not required when virtual-reality simulation is used. They allow practice at varying levels of difficulty, can simulate complications and automatically provide objective measures of assessment, allowing for both formative and summative trainee assessment.[15]

There are many virtual reality simulation models like Tendon transplant simulator, Cholecystectomy simulator, Graphic simulation of abdomen, Visible Human Project; anatomic modeling, Limb trauma simulator, Liver surgery simulator, Intravenous insertion simulator, Sinus endoscopy simulator and Arthroscopy simulator etc. VR simulation has been found to reduce operative time and to improve the performance of surgical trainees.[16]

6. **RAS simulators:** Robot-assisted laparoscopic surgery (RAS) simulators are new development in the field of simulation. The da Vinci surgical system, first introduced in the United States in 1999, involves a surgeon using foot pedals, dual hand controls and a controllable 3D camera to guide a robot through surgical procedures.[17] The da Vinci system's design makes it naturally suited for VR simulation. With the use of a simulator, the surgeon views a virtual environment rather than a live endoscopic feed through the user interface. These simulators are low-fidelity and thus only allow practice of individual surgical tasks testing hand-eye coordination, tissue manipulation, suturing and knot tying.[18]

FUTURE INNOVATIONS IN SURGICAL SIMULATIONS

Rapid prototyping and patient specific virtual simulation will be the main focus area in future to achieve highest level of fidelity.

1. **3D rapid prototyping:** It uses medical imaging techniques like CT and MRI and builds synthetic models of patient-specific organ and vasculatures. Therefore, it becomes easier to plant various operations due to remarkable realism.[19] Mostly they are being used in neurosurgery and cardiac surgeries. Still there is scope of improvement in this technology.

2. **Patient-specific VR simulators:** These are the models that accurately represent specific patients by using patients imaging data. These simulators allow surgeon to practice a procedure preoperatively of that specific case only and hence highest level of fidelity is achieved. Anatomically accurate VR simulations with patient-specific anatomy eliminate the risk of human error and allow visual communication of the surgical plan not just with team members, but with the patient's themselves.[20] These simulators have been developing with upgraded technology and precision day by day.

DISCUSSION

Attaining surgical competence is an intricate process. In depth knowledge, surgical skill, right judgment and professionalism all are equally required for it.[21] *Sushruta* has always emphasized on surgical skills and stated that, "an intelligent surgeon who has tried his hand practicing surgical procedures will never lose his presence of mind in his professional practices".[22] For the past century, surgeons have been taught through the Halstedian model of surgical training, which involved learning the craft of surgery through apprenticeship.[23]

At beginning, these surgical practices were performed on plants, animal parts and human cadaver. Then various animal models and bench top models came into existence in the past century. But they were only capable of providing basic surgical skills like taking incision, excision, suturing and knot tying. Ethical concerns associated with Halstedian approach and animal models; and lack of realism in bench top models has called for changes in these kinds of approaches. Then high fidelity bench top models came into existence and designed to replicate and train complete operations like aneurysm repair, joint replacement and fracture fixation.

Advancement in computer technology has given opportunity to develop virtual simulators. They are high fidelity models and have high degree of realism without the need of patient, cadaver or animal. They are designed to teach laparoscopic, endoscopic and percutaneous intervention. It trains medical professionals by imitating situations that are encountered in real life. Apart from this, modern advances in technology have also enabled the development of surgical simulators that would be capable of replicating complex surgeries; those are unique to the anatomical variations and disease states of actual patients.

In future, innovations in surgical simulation will mainly be focusing on improving surgical outcomes by increasing the operating expertise of operating surgeon. 3D prototyping and patient-specific VR simulators have potential to reach that outcome. Currently they are being used in cardiac and neuro-surgeries.

CONCLUSION

Experimental models or simulators allow the surgeon to acquire the skills before operating on a live person. Thus, the surgeon becomes familiar to operative procedures and more competent to handle intra-operative complications. It helps to increase speed, efficiency, automaticity, and precision of the surgeon without sacrificing patient's life. All these factors have led to development and advancement in experimental surgical models from time to time. All these innovations in surgical simulators are aiming toward one thing only, "improving surgical outcome".

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