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Microsurgery Training: Are the Live Models Era Coming in to the Tail? – A Literature Review

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Introduction: Microsurgery is a relatively new speciality with steep learning patterns. Before practice in real fields surgeons need adequate training to gain the expertise. Different types of living and non-living simulators are used to gain the efficiency. As the living simulator has issues with complexity, availability, cost, ethical approval and special setting and available resources an alternative less complex, inexpensive, no ethical issues, easily available, effective non-living models are demanded by the trainers.

Objective: Review the relevant articles to see the justification of use of live models for microsurgery training and to see is there any alternative non-living model to replace living model.

Materials and Methods: A PubMed and Google Scholar search for key words '(microsurgery) AND (training)) AND (live models)) AND (non-living models)) AND (education)' were performed in February 2021. Total 422 literatures were found from January 1990 to February 2021. Among them 29 were found relevant with topics. Among them 17 were finally selected for discussion.

Conclusion: Evidences showed non-living low fidelity models are as effective as high fidelity living model in microsurgery training. Many of the studies with ex vivo models have showed promising results which support replacement of live models in basic and intermediate courses. However, those are not sufficient to support for total ban of live models specially in advance microsurgery courses. We are hoping, in near future some blended non-living models may come up using digital or virtual reality technology which can replace the live model era. Further research with highest level of evidences are required.

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1. INTRODUCTION

The history of animal testing is quite long. Ancient Greeks used to perform experiment on animals. Gallen, a roman physician who used pigs and goats for his experiments in 2nd century.

But global concerns about using animals for experiment created some acts and regulations.

The Animals (Scientific Procedures) Act of 1986, also called (ASPA), regulates the use of animals for research, including vivisection, in the United Kingdom. A European directive was implemented in the Act in 2012.

Now, in UK use animals in research needs licence from home office and maintain Russel and Burch 3R's principles called- Replacement, Reduction and Refinement [1]. It's also stated-"a scientifically satisfactory method or testing strategy not entailing the use of protected animals must be used instead of a regulated procedure".

Microsurgery relatively new speciality which started in 1950's. Professor Sun Lee, who was the Pioneer of experimental microsurgery, known to be the 'Father of Microsurgery' used to worked with live rat model [2].

Microsurgery is getting popularity in wide varieties of surgical specialities as it is necessary for various procedures like, replantation, revascularization, vascular anastomoses, nerve repair or reconstruction, free flaps, transplantation and more.

The clinical practice of microsurgery requires an extensive training in different levels to obtain the efficiency and expertise needed for real life performance. Continuous practice or rehearsing also needed to maintain the high level of expertise.

Currently there are two types of microsurgery courses commonly advertises globally for trainees. Basic and advanced. Basic courses are aimed for the trainees who didn't have any microsurgery exposure in the past whereas the advanced courses are for trainees or surgeons who want to improve their pre-existing microsurgery skills [1].

For training or practice of microsurgery different types of models are using worldwide. These can be non-living, living or combined models.

Prosthetic, cadaveric animal or cadaveric human are commonly used non-living models in most of the training program or courses. Many of them are formally validated, such as diathermy or rubber pad, polyurethane card, silicon tube, chicken leg, rat femoral artery, porcine eye etc. On the other hand some non-validated models were also used in training, e.g. surgical gauge, beads, gloves etc. Rats and pigs are the frequently used live models [3].

Table 1 shows the example of different models used for microsurgery training.

Live models are still widely used model specially for advanced microsurgical training. Rat is considered as 'gold standard' by many microsurgical training institutions (Fig. 1). It is used as an important tool for microsurgery teaching and training. It gives a real field feeling with similar complexities and physiology in live human tissue with blood flow, tissue perfusion and clotting which can affect the patency. However, it is costly, needs ethical approval, and special technical facilities and settings with available resources. It also requires anaesthesia and longer time for training.

Non-living simulations are getting popularity to avoid the disadvantage of live models. Most of the basic and intermediate part of the microsurgical skills are now achieve by synthetic (Fig. 2) or cadaveric (animal/human) simulation courses with limited recourses. Ex vivo fresh chicken models are one of the easily available most widely used non-living simulator (Fig. 3).

Development of multiple non-living simulators, some of the outcome was very close to those of live models challenging the use of live model for microsurgery training.

2. OBJECTIVE

Review the relevant articles to see the justification of use of live models for microsurgery training and to see is there any alternative non-living model to replace living model.

3. MATERIALS AND METHODS

A systematic review of literature was done on February 2021, using Preferred Reporting Items for Systematic Review and Metanalysis (PRISMA) search protocol. (Fig. 4) A PubMed and google scholar search for key words '(microsurgery) AND (training)) AND (live models)) AND (non-living models)) AND (education)' were performed. All journal articles, abstracts, systematic reviews and randomised controlled trials (RCTs) are included in to the search from January 1990 to February 2021. Total 422 literatures were found among them 29 were found relevant with topics. After reviewing the abstracts the less relevant and duplicated topics were excluded and 23 articles were selected for full text review. Further 6 articles were excluded because of unavailability of full text or found less important and finally 17 articles were selected for discussion (Table 2). Each of the relevant article was carefully reviewed and outcome were discussed.

3.1 PRISMA Flow Diagram for Literature Search

Literature search has been done in February 2021. Preferred Reporting Items for Systematic Review and Metanalysis (PRISMA) search protocol has been followed, as per chart below. (Fig. 4). Initially, total 422 records identified, however, after exclusion, finally 17 papers have been selected for discussion.

4. DISCUSSION

A systematic review, related to use of different models for microsurgery by Ali Ghanem et al. [5] has cautiously concluded, simulated microsurgery training on low fidelity models can be as effective as on high fidelity models. This review has included five Randomised Controlled Trials.

A randomized clinical trial has done by Ethan D Grober et al. [6] from the department of surgery, University of Toronto, Canada . They assessed fifty junior surgery residents participated that trial. Those trainees were enrolled in one day microsurgery training course. They were randomized into 3 groups, one group has practiced on a high fidelity model (live rat vas deferens), the second group has practiced on a low fidelity model (silicone tube) and the third group was didactic training only. The results clearly showed the higher performance in hands-on training groups, however, there were no significant difference between the low fidelity compared to the high fidelity group.

Conclusion was made from this level one evidence (RCT) that microsurgery skills acquisition could be obtained using low fidelity models as because it appears to be equally effective as high fidelity model in training.

In case of microsurgical flap training, live models are popular and commonly used, however Ignacio J. Cifuentes et al. [7] showed in their study that, ex vivo model (chicken leg) can be alternative of live model. In their study they have used 15 chicken legs for perforator flap dissection and concluded it as economical, easily obtainable and readily accessible for continuous microsurgery training.

Tarak Agrebi Moumni Chouri et al. [8] from Aberdeen University, Scotland, UK, used fresh frozen cadaveric limbs which perfused by injecting gelatin and dye mixture to improve visibility and realism of perforators and pedicles. They reviewed the feedback from 50 trainees and assessed confidence, operative skills, transferable procedural based knowledge from training. They have concluded, enhance fresh human cadaveric model could be cost effective, easily reproducible and significant improvement of microsurgical training potential. It can give better training including clearer idea about anatomy as well as can be used for flap training.

Another study by Cristina Pires Camargo et al. from Brazil [9] introduce oxen tongues as a non-living effective model for microvascular training specially for beginners and intermediate trainees. They found significant higher confidence level compared to pre training confidence level using Likert scale.

A study by Georgios Pafitanis et al. [10] assessed forty trainees after a 5-day microsurgery course on non-living model (chicken thigh). Among the trainees, 11 were undergraduate medical students (novices), 12 were core surgical trainees, and 17 were higher specialty trainees. On day 5 of the course they performed the chicken thigh adductor profundus free muscle flap using microscope. The time of anastomosis and flap raising assessed of the 3 groups. Trainees feedback also analysed. From this study they concluded that the chicken thigh model can improve surgeons' microsurgical skills when introduced at the early stages of the learning curve which can replace, reduce and refine the use of live models in microsurgical

training. This model has been recommended for its advantages, like- low cost, constant, and reproducible anatomy and avoid complexity of live models.

Joseph N Carey et al. [11] from Division of Plastic & Reconstructive Surgery, Keck School of Medicine of the University of Southern California, Los Angeles, USA. They used perfused fresh human cadaver models for 38 procedures over 8 months. All cadavers were taken within 4 weeks of death. Procedures were done by all levels of trainees. Different kinds of perforator flaps, muscle flaps, and fasciocutaneous flaps have been performed. Effective perfusion has checked with IndoCyanine Green (ICG) angiography. Although it is a high fidelity model and objective gains in surgical skills are not measured but it is a realistic simulation, which can help to avoid or reduce the necessity of live models.

Jose R Rodriguez et al. [12] published the outcome of their RCT on Non-living models. It was a double blinded RCT on year 3 general surgical residents. The authors aimed to develop and validate a microsurgery training program based on non-living models and assess the transfer of skills to a live rat model. 17 sessions of arterial and venous end to end anastomoses on ex vivo chicken model were assessed by double blinded experts using validated scales and checklists. During the assessment operative time and patency rates were checked. At the end of the training there was a comparison session on live model has been arranged between trainees and experienced surgeons. Results were found statistically significant improvement of microsurgical learning curves (GRS Pre and Post training, 10 vs 28) and interestingly, there were no difference of Global Rating Scores (28 vs 28) between trainees and experienced surgeons. Author found microsurgical skills acquisition by trainees from training on non-living model were similar level of experienced surgeons. Acquired skills were compared by transferring it to more complex live model. This study supports to validate non-living training models.

Gyojun Hwang et al. [13] performed a survey among the participants to choose a model for accuracy and practicality after a '2 days microsurgery course' on synthetic tubes, chicken wings and live rats models. All of the trainees (100%) have chosen the live rat model for improvement of skills and accuracy whereas chicken wing has found to be more practical. Authors recommended chicken wing model for training of new surgeons whereas live rat model was recommended for experience surgeons to maintain their skills.

Evgenios Evgeniou et al. did a literature review on microsurgical simulation and concluded an ideal model should meet some criteria, e.g. realistic, easily available, cheap, feels like biological tissue, avoid ethical issues etc. They have advised combination simulation modalities which included both high and low fidelity models. [4]

There was a study from Leuzzi S et al. [14] on lymphatic microsurgery course using a live rat model.

They used ten norvegicus rats as a live model for their study. They performed multiple lymphatic-venous anastomosis between lumbar node vessels and right lumbar vein. They found average anastomotic time was 49.8 minutes and patency rate was 70%. Having the diameter of lumbar lymphatic vessel was 0.26 mm and right lumbar vein was 0.84 mm, live rat module can be a feasible model for lymphatic microsurgery training

Singh M et al. [1] did a cost analysis on a five-day Microsurgery Training, they found non-living models are much more cheaper and hassle free than live models.

A systematic review article has been published in Archive of Plastic Surgery by Leung CC et al. [15] *from Academic Plastic Surgery Group, Barts and London School of Medicine and Dentistry, UK.*

The authors have performed a survey as well as systematic review of articles and identified 39 microsurgery courses worldwide those are provided by 27 centres. They noticed two third of the courses still used live models for their training, however the cost of advanced courses are double than a basic course.

Alser, O et al. [16] also from Academic Plastic Surgery Group, *Barts and London School of Medicine and Dentistry, UK.*

Fig. 1. Rat- still a 'gold standard' live model for microsurgery training

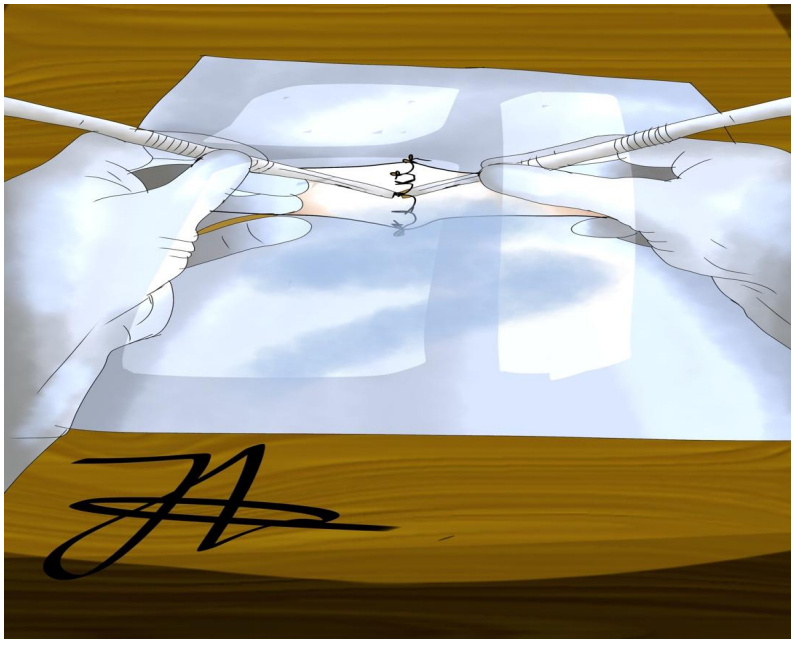

Fig. 2. Microsurgery training- Synthetic model is still one of the key part of basic microsurgery courses

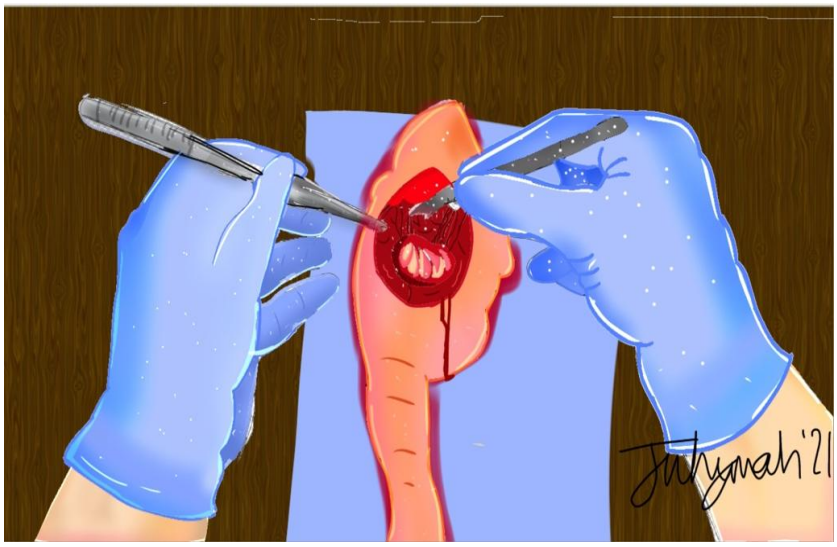

Fig. 3. Ex vivo Chicken leg or wing model, one of the mostly used easily available cadaveric model

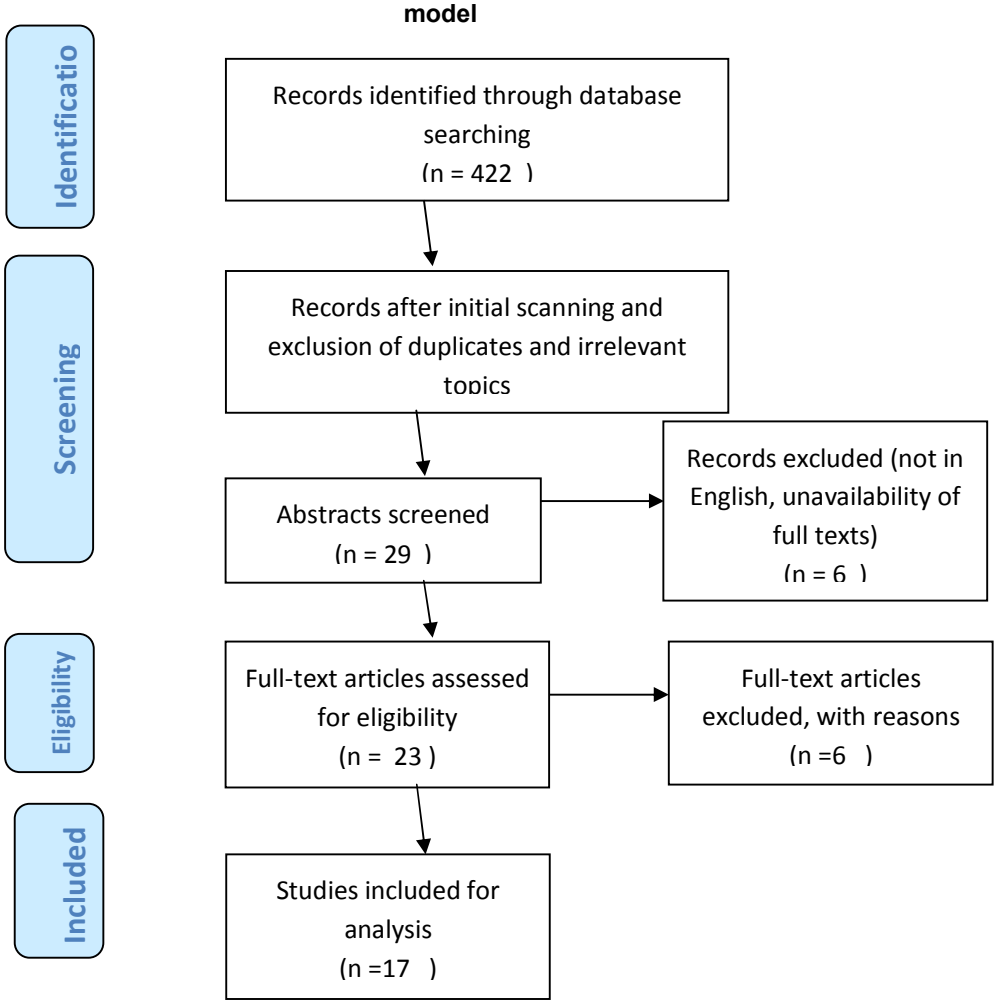

Fig. 4. PRISMA flow diagram

Table 1. Models used for microsurgery training [1,3,4]

Non-Living Models		
Synthetic	Rubber gloves,	
	Gauge,	
	Wooden beads	
	Mepitel dressing	
	Silicone tubes, PVC tubes, Cannula tube, Polyurethane, Gore-Tex	
	Synthetic artery, vein, nerve with fascia (SynDaver)	
	Practice Rat, PVC Rat	
Biological	Non-living animal	Chicken- wings, legs
		Rat- Cryopreserved, freshly killed
		Pork- Porcine eye, thigh, foot
		Other- Earthworm, bovine placenta
	Cadaveric human	Fresh cadaver, umbilical cord, placenta
Living Models		
Rat		
Pig		

Table 2. Relevant articles

S/N	Authors	Country	Journal	Year	Study type	Results	Conclusion
1	Evgenios Evgeniou et al. [4]	UK	Journal of Surgical Education	2018	Review article	Basic level training used solely synthetic models. Intermediate level used mostly cadaveric animals, sometimes cadaveric human and rarely live rat models. Advance level used some cadaveric human and mostly live models.	To achieve comprehensive microsurgical skills a combination of low and high fidelity models has advised.
2	Ghanem AM et al. [5]	UK	APS	2013	Systematic review	Lab based training can significantly improve the skill retention for the trainees. Senior surgeons also can maintain the skills through this way if less exposure of cases.	Cautiously concluded that simulated low fidelity models can be as effective as high fidelity models.
3	Grober ED et al. [6]	Canada	Ann Plastic Surgery	2004	RCT on 50 trainees	There is no significant difference in global rating score between high fidelity and low fidelity models	Low fidelity models can be as effective as high fidelity models in case of novice surgeons.
4	Cifuentes IJ et al. [7]	Chile	J Hand Micro surgery	2016	Prospective study on 15 chicken leg	10 legs used for anatomical dissection, 1 used for angiographic study and 4 used for flap raising.	Flap raising training also possible to ex vivo models
5	Chouari TAM et al. [8]	UK	EJPS	2018	Literature review and study on cadaveric hands	Significant increase in confidence and comfort on flap raising skills. Relatively cheap compared to other high fidelity models.	Injected cadaveric models are low cost and effective and reliable methods for microsurgical training to raise free flaps

Table 2 continued……

6	Camargo CP et al.[9]	Brazil	Acta Cir Bras	2017	Prospective study of microsurgical dissection and vascular anastomosis on 10 cadaveric oxen tongues	Confidence level by Likert scale, pre course 69% and post course 92%.	Oxen tongues are feasible, low cost microsurgical training models which can significantly increase the confidence of the trainees.
7	Pafitanis G et al. [10]	UK	APS	2017	Prospective study of microsurgical courses using Chicken thigh	40 trainees of different levels have completed the courses. 90% of trainees were strongly recommended the chicken thigh model for microsurgical training.	Chicken thigh is a low cost with constant anatomy model and recommended for early stage trainees to reduce the use of animal models.
8	Joseph N. Carey et al. [11]	USA	JPRAS	2013	Prospective Cadaveric Study	38 procedures were performed on fresh, perfused human cadaveric models. It gives same feeling of actual operation.	Perfused fresh human tissue can be a good models for microsurgical training which can provide high fidelity means of training.
9	Rodriguez JR et al. [12]	Chile	PRS	2016	Prospective study on microsurgical training on both non-living and living models	Before basic training (non-living models)trainees Global rating Score was 10 for artery (6-30) and 8 for vein whereas experience surgeons have high GRS (28-29). After basic training (17 sessions), trainees have reached the same score as experienced surgeons (28). In live models trainees and experienced surgeons didn't show any difference in score (28 vs 28)	A non-living models training program was developed and validated.

10	Hwang G et al. [13]	Korea	J Korean Neuro surg Soc	2010	Prospective study on combination (synthetic/ex vivo/live) models	90% of responders were suggested to introduce microsurgery training in chicken model and 100% were in favour of rat model.	Although living rat model found to be most accurate, however, chicken wing model was most practical for microsurgery training.
11	Leuzzi S et al. [14]	Italy	J of Surgical Oncology	2018	Prospective study of LVA on 10 living rat model	Intra operative patency rate 70% with mean lumber vein diameter was 0.84mm and mean abdominal LVs diameter was 0.26mm	Live rat model could be a novel, cost-effective and simple model for lymphatic microsurgical training.
12	Singh M et al. [1]	UK	APS	2014	Cost analysis of different models	Each live rat model cost $30 as well as home office licence for animal experience is $384.7 whereas each chicken leg costs only $0.97 and per cm silicone tube is only $0.07.	Non-living models are far much cheaper and hassle free (ethical and hygiene advantage) than living models.
13	Leung CC et al. [15]	UK	APS	2013	Systematic review + survey	39 courses in 27 centres were identified. Mostly basic microsurgery courses, very few run advance courses. Most of them are 5 days course. Cost of attending basic microsurgery course is an average of $1236 and for advance course is $2328.	2/3 of courses use live models. The cost of advanced courses are double the cost of Basic courses

14	Thomson JE et al. [17]	USA	APS	2017	Systematic Review	13 papers have reviewed. Virtual simulation can be cost effective in the long run and trainees can be benefited by learning through the repetition. Animal models are loosing their popularity due to ethical concerns and cost. Perfused cadaver can be the replica of live models.	Stepwise use of different models advised in different stages of training
15	Alser, O et al. [16]	UK	Eur J Plast Surg	2020	Analysis of feedback on Surgitate 3 in 1 silicon slab model from 14 MSc (Microsurgery) Students	93% trainees recommended Surgitate model for basic microsurgery training and excellent model for preparation before work on human tissue.	3 in 1 silicon model has proposed for basic microsurgical training alternative to common synthetic or animal models and ideal to meet 3R principles.
16	Brown JS et al. [18]	UK	BJ O&MS	2019	Systematic Review	Simulation training is needed after formal teaching and instruction	There are Lack of evidence to justify the use of live models in microsurgery training
17	Ramachandran S at el.	Singapore	APS	2013	Ideas and Innovation	Chicken heart is cheap model cost about $0.04/heart. Good calibre of aorta (4mm) gives suitability of practice and patency check.	Chicken aorta is low cost, easily available, less biohazards given suitability of early stage of microsurgical training.

They did an analysis of feedback received from 14 MSc Microsurgery Students who used Surgitate 3 in 1 silicone slab model during their hand on training. According to this analysis they found this model is an excellent for acquisition of microsurgical skills before work on human tissue.

In 2017, another systematic review article by Thomson JE et al. [17] was published in Archive of Plastic Surgery, where authors advised step wise use of low to high fidelity models in different levels of training.

Brown JS et al. [18] concluded from their systematic review, there are still no sufficient evidences to justify use of live models in microsurgery training.

Ramachandran S et al. [19] found chicken aorta can be a good model for early microsurgery training.

5. CONCLUSION

There are many models have been described in the literatures for simulation in microsurgical training. Live animals model specifically live rat model still thought to be gold standards for training of microsurgery. It is a realistic simulation by having anatomical and physiological environment very close to the clinical setting. However, it has significant ethical barrier, cost, and needs for special settings and adequate resources. The ideal training model should be without ethical issues, realistic, inexpensive, easily available, and similar or close to the clinical setting. Evidences showed non-living low fidelity models as effective as high fidelity living model in microsurgery training. Many of the studies with ex vivo models have showed promising results which support replacement of live models in basic and intermediate courses. However, those are not sufficient to support for total ban of live models specially on advance microsurgery courses. We are hoping in near future some blended non-living models may come up using digital or virtual reality technology which can replace the live model era. Further research with highest level of evidences are required.

CONSENT

No informed consent was required for the development of the literature.

ETHICAL APPROVAL

No ethical approval was required being a literature review.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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