The more things change, the more they stay the same: technology surges forward but the patient's symptoms are constant

Margot Cooper

Author details:

Margot Cooper
E-mail:
margot.cooper@limbsandthings.com

Abstract

The aim of this article is to outline the different elements which are employed in the design and manufacture of successful models and simulators in medical skills training. It will also place the patient at the centre of this focus. Since my last paper outlining the development of surgical and clinical training on models and simulators between 1990 and 2008, much has changed. The patients' symptoms are likely to have remained the same over the years, but the approach and diagnostic opportunity will not be the same. The patients' needs continue to require skilled professional treatment; this treatment has changed. Whether it has become more or less efficient depends on the equipment and facility available at the time. The trainee needs to learn how to manage the patient, how to become proficient in the required diagnostic techniques, and how to master the equipment used in the treatment of the patient. In designing the optimum opportunity for training health care professionals, technology has offered a wider choice of simulation solutions. This paper focuses on the needs of the patient, and on the scope of established and new technologies, which are enriching the training process.

Key words: Limbs & Things, Trainer, Part task trainers, Hybrid training, Ultrasound, Virtual reality, Haptic systems, Augmented reality, Integrated simulators, Mannequin, Micro-surgery anastomosis, Paracentesis, Abdominal examination

Introduction

Health care professionals

The working environment for healthcare professionals (HCPs) is changing, shaped by high volumes and time pressures, but at the centre of clinical activities remains the patient. Whether he or she requires a relatively simple consultation or clinical treatment, or is undergoing a long operation, the patient continues to be the main focus of the activity.

In treating patients effectively, HCPs must master many skills. These range from hands-on diagnosis to minor or more complex surgical skills. Increasingly, technology has been introduced to aid learning and procedure, with which the HCP must be familiar. A multi-disciplinary team of specialists often contribute to treatment decisions and the use of sophisticated equipment and materials and communication is increasingly important to master.

The training process

During the last decade, training programmes for all of these techniques and skills have been widely established using simulation. Each undergraduate course and medical discipline has structured curricula of training and examination, where possible including models and simulation to learn hands-on skills. Gone are Halsted's days of: "See one, do one and teach one", as competency-based learning curricula take the fore. New technologies can be safely introduced and explored, and scenarios can be simulated to improve interaction in multi-disciplinary teams.

Simulation is used in the following forms:

- Soft tissue part task trainers with or without electronic feedback.
- Soft tissue models, which are worn by a person; so-called hybrid training.
- Soft tissue parts held on a jig for the practice of surgical procedures.
- Virtual reality used to recreate environments or objects as a complex, computer-generated, often interactive image.
- Haptic systems replicating kinaesthetic and tactile perception and producing a feeling of resistance when using instruments within a simulated environment.
- Augmented reality, which superimposes a computer-generated image on a user's view of the real world, thus providing a composite view.
- Integrated simulators combining a mannequin with sophisticated computer controls that can be manipulated to provide various physiological parameter outputs that can be physical, e.g. pulse rate or respiratory movements, or electrical, e.g. monitor readings.
- Monitoring and assessment using technology to track trainees' actions during a procedure and provide task-specific feedback against given criteria.
- Learning content such as Computer-assisted Learning, Mobile Devices and Games. Often, a combination of these different modalities will be employed.

The focus of Limbs & Things

The work of Limbs & Things revolves around soft tissue simulation of parts of the body. Our mission has always been work with clinicians to answer specific and relevant training needs. We aim to innovate, maintaining awareness of and employing the latest and up-coming technologies. In doing so, we have continued to design and structure our products in line with the needs of leading educationalists in medicine and surgery. Well thought-out models can offer staged and structured training according to the principles of the specialty, institution and/ or course director.

By way of example, four of our latest developments are outlined highlighting the drivers in the market, growing demands from our clients, and the introduction of appropriate innovation and technologies.

MICROSURGERY ANASTOMOSIS TRAINER:

Anastomosis is the art of suturing two circular structures together; all surgeons must be practised and efficient in the technique of anastomosis, since it is likely that the structures will need to hold fluid of some sort.

Limbs & Things has produced models for anastomosis for a long time ranging from 30 mm to 3mm diameter; these models have offered training in the basic techniques for a variety of complexities of structure and situation. However, we have never previously addressed microsurgery, which involves vessels sometimes smaller than 1mm in diameter with an accurate representation of arterial and venous structures.

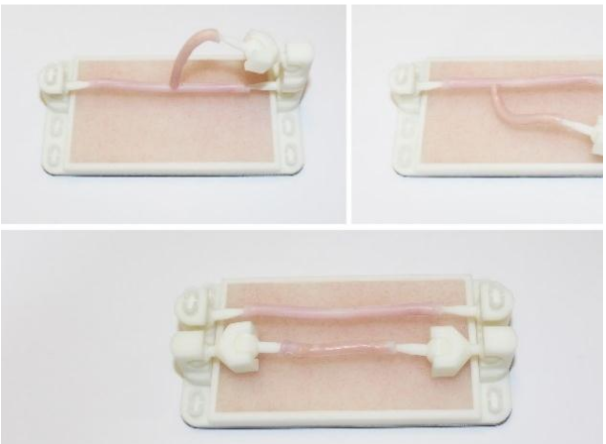

Figure 1: The base of the jig showing the accommodation of the required angles for presentation of the vessels.

- The arteries should present the 3 layers accurately- adventitia, media, and intima with a maximum lumen of 1mm (see *Figure 2*).

Objectives of the trainer:

- To provide a rigid jig to hold vessels in parallel; "end to side", perpendicular to each other in the horizontal plane; "end to side" at 30 degrees from above. The arms should be mobile so as to accommodate the vessel as it gets shorter until there is only a stub left (see *Figure 1*).

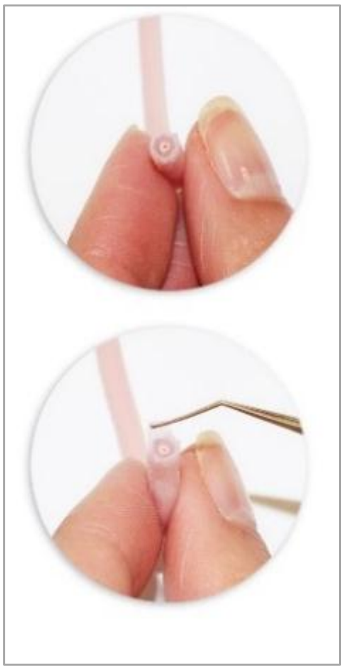

Figure 2: The arteries have three layers: an intima, media and adventitia.

- The veins should present adventtia and media with a lumen of 2mm.
- The trainer needs to fit under a microscope.
- The trainer needs to fit into a pocket, to be available for practise or warm-up when required. This is particularly useful for training fellows and registrars (in the UK), residents (in the US). See *Figure 3*.

Figure 3: The complete jig, the size of a telephone.

The trainer should be usable with synthetic as well as animal vessels, although different training environments may dictate that only synthetic products can be used, e.g. when training using the microscope in theatre.

- Ideally the vessels should be possible to test with fluid to prove the joining anastomosis.

We were presented with two main challenges:

Challenge 1: To create 3 arterial layers all of different qualities, and adherence one to the next:

- The adventitia is stretchy and floppy with no memory;
- The media is delicate but strong;
- The intima is fine and can be 'caught' on the backwall by a careless surgeon, occluding the lumen.

Challenge 2: To design the jig for multiple task and make it no bigger than a telephone whilst storing the arms, conectors, sutures and vessels.

These challenges have been resolved by the creation of bespoke materials and very clever design (see *Figure 4*). 3D printing has speeded up the process of prototyping the tools and jig.

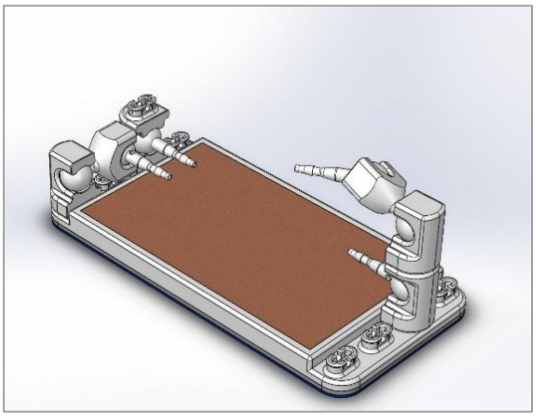

Figure 4: The design offers the possibility to accommodate different structures.

SHOULDER FOR SOFT TISSUE JOINT INJECTION TRAINER WITH 2 MODULES

We have carried the shoulder in our range for decades. It has had various upgrades, but the time has arrived for a complete change, as training with ultrasound is now recommended. Ultrasound guided joint injections are part of speciality training in areas such as clinical radiology, rheumatology and orthopaedics in the US and the UK. The use of ultrasound techniques are increasing across other specialties too, to the extent that the Royal College of Radiologists have published training recommendations for medical and surgical specialties. [1]

Objectives of the trainer:

- Movement in the head of the humerus over 110 degrees (see *Figure 5*)

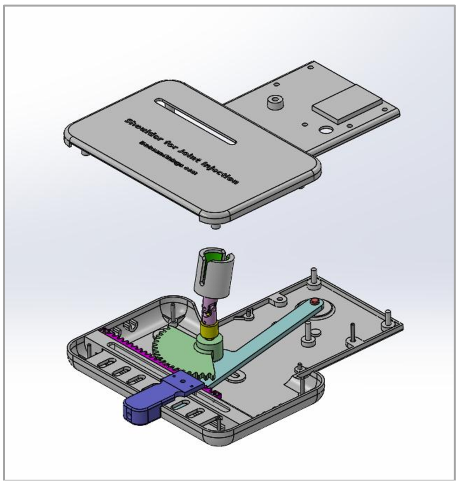

Figure 5: A mechanism designed to draw the humerus easily across 110 degrees

- Accurate bony anatomy (see *Figure 6*)

Figure 6: Correct anatomical landmarks designed and printed using Computer Aided Design (CAD)

Ultrasound module:

- Access of fluid within the ultrasound module and visibility of injectate entering the joint and bursa system (see *Figure 7)*

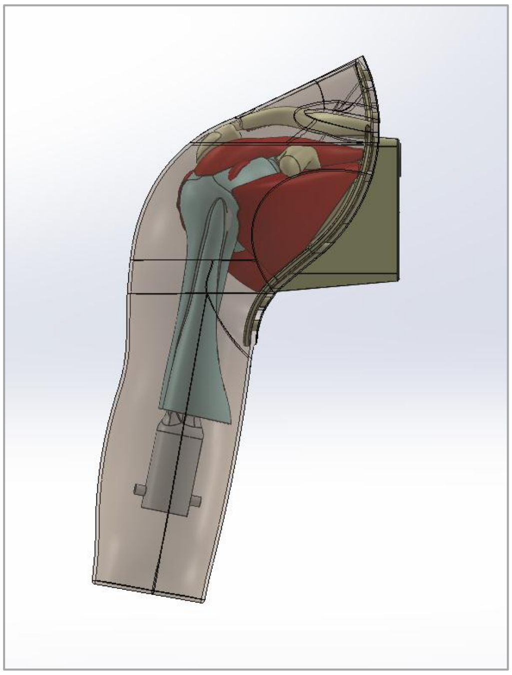

Figure 7: CAD design of complicated internal fluid filled joints and bursae

- Ultrasound reading over skin, fat, muscle, ligament and bone (see *Figure 8*)

Figure 8: Various textured materials which make up the shoulder to give an accurate ultrasound reading, below the level of the skin.

Dry/electric model:

- Needle to work remotely with feedback of positioning to a receiving tablet
- App on the tablet for readout in real time. Also serving as a training platform.

Resolving the objectives

Movement of the humerus:

Extensive study revealed to us exactly how the humerus is required to move during access to the range of injection sites. A working jig was build to test the strength of the joint; it ran for 10,000 tests and still the humerus remained robustly fixed.

Ultrasound module:

In order to gain an ultrasonic image exactly like the body, we needed to formulate new materials which are radiolucent. These we could then back fill with textured material to give the right reading of tissue, bone, fat etc.

Pockets of liquid relate accurately to the joint capsule and bursae in the shoulder joint; they are often hard to find. With this model not only is the anatomy and size of bursae accurate, but under ultrasound the injectate is seen entering the other fluid.

The dry/electric model:

Many iterations and innovative design enabled us to arrive at a system which allowed that degree of movement and accurate access of injection sites with wireless feedback to a screen. The corresponding computer application has been built in-house and is web-based. This allows the accommodation of all of the platforms and the ability to make changes as necessary. (See *Figure 9)*

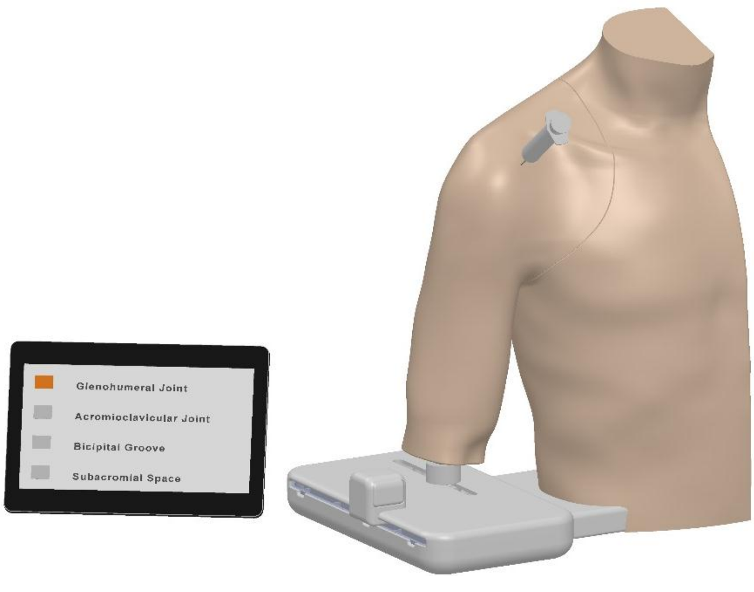

Figure 9: model with needle and app

Unlike our earlier model of the shoulder, it is completely designed on CAD and 3D printing has been an aid in its development.

PARACENTESIS TRAINER:

Paracentesis is the surgical puncture of a cavity for aspiration of fluid.

Generally, when this skill is required, a patient presents with a distended abdomen and in a lot of pain. There is fluid in the abdominal cavity, which makes it difficult to breathe and can obstruct the venous return. To relieve these conditions, paracentesis is performed under ultrasound guidance.

It is an invasive procedure, risks damaging surrounding structures, and can be painful if not carried out with skill. It is therefore difficult to train on a distressed patient. One study: 'Effectiveness of an Ultrasound Training Model for Internal Medicine Residents' concludes that simulation training in this context is of great benefit. [2]

Objectives of the model

- To create a torso/trunk with replaceable soft tissue pads on either side of the abdomen.
- To enable the soft tissue pads to be fitted and injected many times whilst containing pressurised fluid.
- To enable the procedure to be carried out under ultrasound guidance (see *Figure 10*)

Figure 10: The visibility of viscera using ultrasound enables the safe insertion of the needle.

- To ensure that the pads withstand multiple piercings with a green needle and a Rocket safety drain with no resulting leak. (see *Figures 11 & 12*).

Figure 11: The insertion of a Rocket safety drain.

Figure 12: Fluid draining via a Rocket safety drain

To create a low-tech pump to refill the abdominal cavity to target pressure of 15-30 mmHg.

- To include viscera within the cavity to create anatomy which should be avoided when using needles.

Resolving the objectives

In reality, the patient's abdominal wall is stretched and is very soft and easy to pierce. Recreating a realistic insertion force of the needle and no leakage on its withdrawal was difficult to achieve. It took a long time to reach the right combination of newly devised and original materials to enable these pads to perform satisfactorily.

To manage a model for a sequence of students, especially in an observed structured clinical examination (OSCE) or sequential examinations, requires that it is quick to replace parts and restore the model to a functional state. Therefore, the pump needed to reduce the fluid level at speed and the pads had to be quick release. These were achieved in this successful model.

ABDOMINAL EXAMINATION TRAINER

From the earliest stage of a doctor or nurse's training, he or she is taught to learn as much about the patient's condition as possible from observation. Observation in the form of seeing, listening, smelling; the objective is to learn as much about the patient as possible in the least invasive manner.

In the identification of enlarged or changed abdominal organs, malfunct-ioning intestines or fluid within the abdominal cavity, the techniques of palpation, auscultation and percussion need to be practised. In life, the patient is often in a lot of pain and any form of deep pressure of the fingers and hand would cause a lot of pain.

Our market research called for a model in which various conditions could be simulated for hands on diagnosis; the key focus was to create a manual model which felt just like a patient's abdomen and which was not reliant on electricity. There is little reference to previous trials with such a model as, to our knowledge, there is none. There are models in the market for abdominal examination which are designed for training in diagnosis using ultrasound guidance, but not offering the opportunity of 'hands on' palpation.

A practical guide to clinical medicine- Exam of the abdomen' offers an explanation of the complexity of the condition ascites, and a rudimentary model for understanding the concept of shifting dullness. [3]

Objectives of the model

- To represent the abdomen, pelvis and lower part of the thorax including the thoracic and lumbar spine.
- To include two to three variations of the liver, spleen, kidneys, bladder and aorta, including smooth and irregular hard masses to identify.
- To replicate fluid distension of the abdominal wall which moves according to gravity when the patient is turned onto the side of the body (ascites).
- To simulate realistic breathing, bowel and vessel sounds.
- To feel realistic on palpation in texture and pressure.
- To enable percussion to elucidate sounds which change according to the underlying tissues, organs and bones.
- To allow auscultation with and without stethoscope.
- To include both transmitted and expansile aortic pulses, the latter to demonstrate an aneurysm.

Resolving the objectives

This development is an example of smart design being the key to creating the impossible! (see Figure 13)

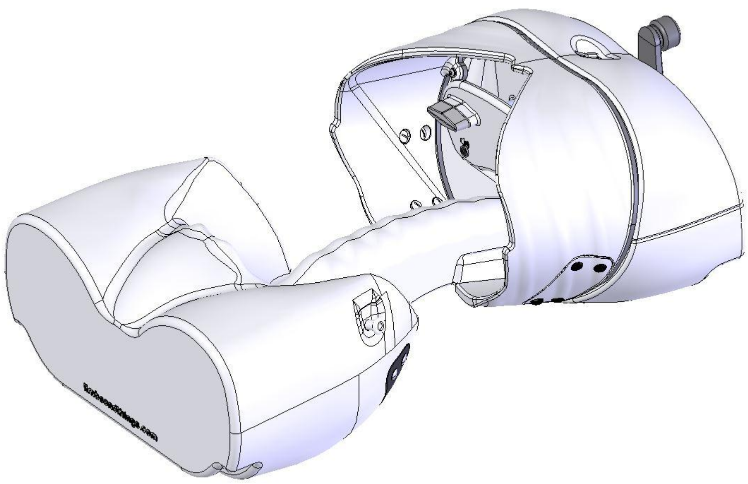

Figure 13: The main assembly of the abdominal examination model

The model is designed to be used in all parts of the world, in all situations. We used fluid filled bags, hand held pulse bulbs and easily fixed and quick release fixings for the wide variety of organs.

Different combinations of the organs and their various presentations provide an enormous offering of symptoms and diseases (see *Figure 14*).

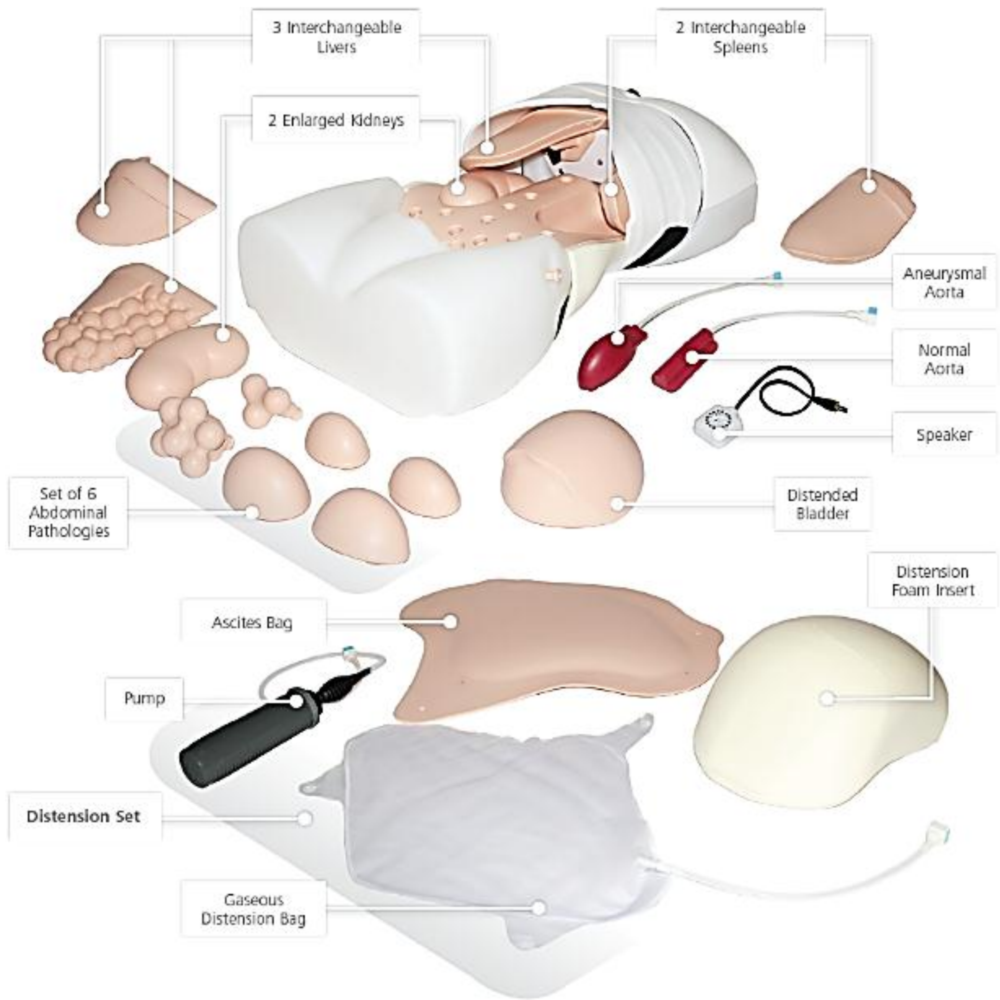

Figure 14: The abdominal examination model with all the modules

Conclusion:

There is a recognition that technical skill is better retained after training which is spaced out rather than clumped together.[4] There are also practical and ethical issues with practising on patients. Finally, there is a shift from the "See one, do one, teach one" approach to learning to a deliberate practice model where competency-based feedback guides progress.[5] Most of the forms of simulation mentioned at the beginning of this article offer the opportunity of learning skills in one's own time at one's own pace at the most opportune moment available. The exceptions are the big patient simulators, which are designed for team training, and some virtual reality systems, which have to be locked away when not in use due to the high purchase price.

As the time pressure on trainees continues to mount, and the opportunity of practising skills whilst at work diminishes, it is becoming more important to offer models and simulators which are either portable, or can be conveniently placed closer to the trainee's day to day activities. Limbs & Things will continue to develop and offer part task trainers which answer these needs with the central focus of patient care. The introduction of new technologies may enrich their efficiency, but while all these change, the needs of the patient and trainee stay the same.

Conflict of interest

The author is the majority shareholder of Limbs & Things Ltd.

References

1. Royal college of Radiologists, Ultrasound Training Recommendations for Medical and Surgical Specialties, Second Edition, 2012

2. Mira T Keddis, Michael W Cullen, Darcy A Reed, Andrew J Halvorsen, Furman S McDonald, Paul Y Takahashi, and Anjali Bhagra, Effectiveness of an Ultrasound Training Module for Internal Medicine Residents, BMC Med Educ. 2011; 11: 75. Published online 2011 Sep 28. doi: 10.1186/1472-6920-11-75

3. Exam of the Abdomen, A Practical Guide to Clinical Medicine, University of California, https://meded.ucsd.edu/clinicalmed/abdomen.htm (Accessed June 2017)

4. Nicholas RS, Madada-Nyakauru RN, Irri RA, Myers SR, Ghanem AM. Research priorities in light of current trends in microsurgical training: revalidation, simulation, cross-training, and standardisation. Archives of plastic surgery. 2014;41(3):218-24.

5. Chan W-Y, Niranjan N, Ramakrishnan V. Structured assessment of microsurgery skills in the clinical setting. Journal of plastic, reconstructive & aesthetic surgery : JPRAS. 2010;63(1329-34).