

The Role of Technology in Skin Surgery

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Abstract Skin surgery, or dermatological surgery is a relatively new specialty. Its infancy has meant that ideas are somewhat flexible and frequently taken up faster than in other more established fields of surgery. This mini-review examines the various roles of technology in each stage of surgery – pre-operative, intra-operative and post-operative.

Keywords: skin surgery, dermatology, technology

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1. Introduction

Technology is indispensable in modern medicine. From getting an appointment in the first place through to clinical coding and archiving, the whole process depends on technology.

For the purposes of this mini-review, only those elements which are of particular relevance to dermatological surgery will be discussed. This is not to say that those concepts omitted are unimportant; case-in-point, the technology used in service delivery is clearly essential [1] but largely common to the various specialties.

Definition:

tech·nol·o·gy [tek·nol·uh·jee]

the practical application of knowledge especially in a particular area [2]

2. Classification of Surgical Technologies

This review will examine technologies in the order in which they may be utilised: pre-operative, intra-operative and post-operative.

2.1. Pre-operative Phase

Dermatologic surgery is an umbrella term encompassing any procedure used to improve or repair the skin. Procedures include excisional biopsies performed during routine practice, cryotherapy for wart removal, as well as Mohs surgery for cutaneous malignancies. Unfortunately, as one moves into areas of greater complexity, the prospect of adverse outcomes, as well as litigation increases. With this in mind, let us discuss the role that technology plays long before the lignocaine is drawn up.

2.1.1. Training

During undergraduate training, students often have the opportunity to practice subcuticular suturing on a variety of ‘organic’ materials acquired from the greengrocers, and eventually on simulated wounds. If one’s first foray into suturing had instead been on an agitated patient during the Emergency Medicine rotation, it is likely that things would have gone wrong. Clearly, competence must be achieved, and ideally demonstrated to have been achieved, before performing any procedure.

As one progresses up the reconstructive ladder beyond direct sutures, fruits and simulated wounds prove increasingly inadequate. While every dermatology trainee must be adept in simple wound closure, those more surgically-inclined may develop proficiency in skin grafting or even the design and execution of local skin flaps. Regrettably, there are limited opportunities for the development of these skills in the clinical setting - pig’s feet having traditionally served as prostheses. This is less than ideal for a number of reasons:

1. This cannot accurately simulate the ‘feel’ or biomechanics of human skin.
2. This is a perishable resource which is suitable for single-use only.
3. The use of pig’s feet is objectionable to certain religious groups.

Cadavers are not satisfactory alternatives in themselves: The national cadaver shortage notwithstanding, they are very expensive to maintain [3], do not bleed and quickly lose the viscoelastic properties of normal skin [4,5]. While it may never be possible to accurately replicate the properties of skin *in vivo*, the use of prosthetic mimics as low-fidelity models has been shown to be an excellent training medium [6,7]. Ingenious proposals by various groups offer worthy alternatives: Polyurethane foam dressing [8,9], rubber sheets [10,11], and, most recently, elastic bandages [12] have all been trialled as skin equivalents for flap training. Moreover, while bioengineered skin may often be prohibitively expensive even as a therapeutic option [13,14] – let alone as a training aid – this may change in the future.

However, the most exciting short- to mid-term prospect is that of ‘virtual simulation’: As one may suspect, in the learning of technical skills such as surgery, repetition in a laboratory setting is critically linked to improving the student’s performance [15,16,17]. Thus, a device which can simulate three-dimensional skin deformations with real-time tactile feedback could yield huge improvements in the standard of surgical education. This is not as far-fetched as it may seem at first glance - crude skin simulators have been in use for more than a decade already [18].

Unlike many other materials, skin is complex, nonhomogeneous and *anisotropic* (i.e. yields a non-linear reaction to a given force) [19]. These attributes, as well as the complex dynamic changes in tension and elasticity produced by incision [20], provide formidable biomechanical challenges to virtual simulation. Fortunately with the inexorable march of processing power [21], many of these problems may soon be overcome by fast finite modelling [22] and brute force, rendering simulation a realistic teaching aid of the not-too-distant future.

Such technology need not be restricted to its educational applications, however. For instance, a patient may present with a technically-challenging medial canthus basal cell carcinoma. The ‘student’, or most probably an expert Mohs surgeon, could practice the exact surgical case beforehand after entering the patient’s specific skin and soft tissue geometries into the simulator.

2.1.2. Dermoscopy

“The dermatologist is a visual libertine seduced daily by the beauty of a rash.”

Professor Sam Shuster

Not too long ago, it was argued that one could measure blood pressure with a skilled finger on the pulse. Certain practitioners even diagnosed diabetes by tasting urine. Sphygmomanometers and urine dipsticks have since refined diagnosis somewhat.

From the beginnings of medicine in Ancient Greece to the modern day, medicine has stood on the foundation of history-taking and clinical examination. Despite newspaper headlines proclaiming ‘NEW SCANNER DETECTS CANCER EARLY’ [23], technology is still merely an adjunct to these methods. As Prof. Shuster alludes to, the dermatologist is a visual creature whose eyes are finely-tuned to detail. However, just as the dipstick has prevented many sour faces, the use of imaging in dermatology is aiding the clinical process.

The dermoscope is a key diagnostic tool, almost ubiquitous in the dermatology department of today. The use of handheld magnification enables the visualisation of subsurface anatomic structures of the epidermis and papillary dermis that are simply indiscernible to the naked eye.

While work by Kittler *et al.* approximates the accuracy of clinical, unaided diagnosis by experienced dermatologists as around 60% [24], the debate around the value of dermoscopy is a highly contentious one. Lending credence to the technique, a particularly rigorous meta-analysis showed an increase in diagnostic accuracy of 49% with dermoscopy as compared to without, with improvements in mean sensitivity and specificity of 19% and 6% respectively [24,25,26]. Of note, however, such

improvements with dermoscopy are seen only in experienced, trained clinicians, emphasising the importance of clinical acumen even with technological assistance [24,27,28].

Until recently, all dermoscopes employed non-polarised light to illuminate the skin. However, new cross-polarised models have since appeared which offer improved image resolution [29]. It is believed that polarised-light devices allow better visualisation of deep structures owing to their ability to reject superficially reflected light more efficiently than their non-polarised cousins. Moreover, polarised devices do not require direct contact with the skin, thereby circumventing the blanching of vascular structures (which may be vital in making a diagnosis) that occurs with previous models [30].

2.1.3. Reflectance Confocal Microscopy

It is sometime said that, “One may only reliably diagnose an infestation of scabies if you catch the critters alive.” While these views may be those of the purist, it would be largely uncontroversial to state that histological diagnosis is the gold standard in dermatology. Unfortunately, procuring tissue samples requires a surgical, albeit minor procedure, as well as subsequent fixation, sectioning and staining - a labour-intensive process which will be returned to later in this essay. Suffice it to say, histology is unrivalled in terms of securing a diagnosis, but counterbalanced somewhat by the cumulative manpower required of biopsy, potential for scarring as well as patient angst over the procedure.

New technology however, in the form of reflectance-mode confocal microscopy (RCM), may be of benefit in certain individuals who would previously have been placed on the biopsy list. *In vivo* RCM is a non-invasive technique that offers *en face* (horizontal plane) visualisation of microscopic structures and subcellular resolution at epidermal, dermo-epidermal and superficial dermal levels [31,32,33]. In RCM, the operator focuses a low-power laser beam on a specific point in the skin, detecting only the light reflected from that focal point via a pinhole-sized spatial filter [34] (Figure 1).

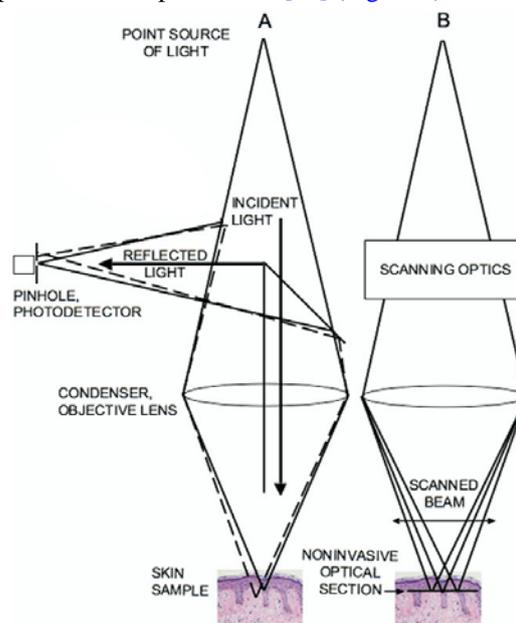


Figure 1. Schematic diagram illustrating how reflectance confocal microscopy works

This beam is then scanned horizontally over a two-dimensional grid to obtain a horizontal 'section'. The focal length of the beam is adjusted, allowing the microscope to image a series of horizontal planes stacked vertically. The eventual three-dimensional (3-D) image is produced by virtue of natural variation in refractive indices between tissue structures. As mentioned earlier, this technique enables a 3-D view of tissue *in vivo*, without disrupting the natural architecture of skin (thereby eliminating potential artifacts) and permits the assessment of details in the same tissue over time [35,36]. Multiple studies have shown that RCM yields distinct morphologic differences between benign and malignant lesions [37,38,39]: avoiding excessive scarring associated with the excision of benign lesions can only be a good thing.

Furthermore, RCM need not be used solely as an alternative to biopsy in borderline cases. RCM can additionally serve a complementary role to biopsy, being used to scan the entire area of the lesion in the horizontal plane; thus areas which show cellular or architectural atypia may be identified for biopsy site selection. This is of particular value in diagnosing certain lentigo maligna melanomas which may display skip areas and foci of invasion [40].

2.1.4. Patient Education

The thought of undergoing dermatological surgery is, for many, an quite unsettling prospect. Moreover, no matter how many times one may supplant basal cell carcinoma with 'rodent ulcer', the nefarious associations of the *C-word* can cause significant distress to the patient.

Before any procedure, patients are informed of the benefits and drawbacks of surgery, as well as potential complications that may arise. Thus, if the patient signs the consent form it is assumed that they appreciate the facts and implications of surgery, and are making a reasoned decision based on the presented information.

The observant clinician will no doubt recognise, however, that while they may discuss the procedure with the patient, the degree of understanding that the patient achieves (and retains) may fall some way short of that required to form reliably *informed* consent. Specific to Mohs surgery, Fleischman and Garcia have demonstrated that patients have knowledge retention of around 26.5% after twenty minutes and 24.4% after a week [41]. A simple but well-designed study led by Tri Nguyen of The University of Texas has revealed a worthy application for the use of high-definition video as a patient education vehicle [42]. Patients in the study were either assigned to a 'video group' or 'non-video group'. In the video group, patients were informed of the procedure by a five minute video with a surgeon subsequently on-hand to discuss any questions arising from the material; in the non-video group, patients had the same information conveyed by the surgeon alone. The study overwhelmingly supports the use of video for patient education on four grounds.

1. Efficiency can be increased by allowing the video to convey time-consuming rote repetition information, thereby freeing up the team to deal with higher-level interactions, such as answering questions.

	Video	No Video
Total physician time (min : sec)	1:02	5:31
Total consent time (min: sec)	6:11	5:31

2. Patients' knowledge of wound care in the video group was demonstrably superior those in the non-video group by some margin.
3. 100% of patients in the video group preferred information delivered in this manner "and would recommend it to friends".
4. It can be verified that every patient in the video group receives identical detailed content, eliminating the possibility of potential omission errors and unwieldy descriptions of the procedure.

The findings of this study are in keeping with previous work highlighting the value of audiovisual content in improving patient satisfaction [43] and comprehension [44,45,46] as well as reducing anxiety [47].

2.2 Intra-operative Phase

2.2.1. Mohs Micrographic Surgery

Conceived by Frederic Mohs in 1930, this technique has since revolutionised modern dermatologic surgery [48]. The procedure provides complete microscopic control of tumour margins and offers superior cure rates to alternative treatment modalities. Usually performed in the outpatient setting, Mohs surgery is a meticulous technique in which horizontal frozen sections derived from the surgical margin of the excised tumour are sent for histologic assessment [49]. Residual malignant extension of the margin is mapped and excised selectively until the tumour is completely removed.

In certain scenarios however, dermatopathological expertise is not available immediately and locally [50,51] – enter telepathology.

Telepathology is the practice of pathology at distance using telecommunications technology to transmit and visualise images on a video monitor rather than viewing a specimen directly through a microscope [52]. Since the ability to make rapid, but accurate decisions on intraoperative Mohs frozen sections is critical to the procedure, ready access to a pathologist is essential [53,54]. However, since Mohs is largely an outpatient procedure, this expertise is often not readily available. Without a willing and available pathologist's opinion, there are several outcomes, all of which are less than ideal:

1. An additional layer of tissue is excised as a safety margin in questionable cases. In critical areas of the face, this can lead to significant functional and cosmetic impairment.
2. The tissue layer in question is sent for paraffin-embedded permanent sectioning, although this delays reconstruction of the wound and inconveniences the patient.
3. Despite the surgeon's best efforts, a residual focus of tumour at the surgical margin is misidentified as a benign structure, leading to tumour recurrence.

Use of telepathology can avoid these pitfalls, obviating any interruption in the Mohs surgery workflow since the surgeon need not leave theatre for a consultation. Additionally, several studies have demonstrated equivalence between conventional microscopy and telepathology [55,56,57]. As with most good things however, there are drawbacks. Establishing such infrastructure may be prohibitively expensive especially in the current climate; there may be concerns about the

security of data transmission [58]; as well as the problematic issue of liability in remote diagnosis [59].

2.2.2. Reflectance Confocal Microscopy

The preoperative role that RCM can play has been already been discussed. However, the use of confocal imaging for intraoperative Mohs tumour margin mapping has been reported since 2001 [60]. Using a technique termed ‘acetowhitening’ (washing excision specimens in acetic acid to enhance contrast), Chung and colleagues demonstrated that confocal images correlated well with standard Mohs frozen section histology in terms of tumour location, shape and margins between normal and tumour tissue [61]. Subsequent work has reaffirmed the value of RCM in the management of basal cell [62,63] and squamous cell carcinoma [64].

2.3. Post-operative Phase

2.3.1. Laser

Lasers have been used in dermatology since pioneering work by Goldman and colleagues in 1960 [65]. This landmark paper has since spawned a virtual subspecialty of its own: lasers are now widely harnessed in dermatology for their therapeutic [66,67,68] as well as diagnostic applications [69,70].

Lasers may also be valuable postoperatively: A literature review was conducted by Posten *et al.* focusing on the use of lasers in wound healing [71]. While the outcome of the review was largely equivocal (some studies were supportive while others showed no benefit), this may be attributed to the significant variation in the quality of studies included in the review, as well as the variety of devices and parameters employed. More encouragingly, however, recent work has shown light and laser therapy to be useful in the healing of excision wounds in a murine model [72].

Just as virtual simulation may be the final frontier for surgical education, scarless surgery may be the epitome of dermatologic surgery as a whole. Practitioners have made various attempts at photochemical tissue bonding over the last two decades [73,74]. The technique involves the localised heating of skin to denature collagen. The eventual tissue bonding that occurs is thought to occur as a result of the intertwining of collagen from the wound edges as the tissue cools. To date, the technology has not been utilised widely owing to inconsistent results and complications arising from tissue overheating. However, work at the Wellman Centre for Photomedicine, Harvard offers renewed promise. Kamegaya and colleagues explored the use of Rose Bengal dye and 1,8-naphthylamide in conjunction with a 532-nm laser to close incisional and excision wounds in a pig model [75]. Analysis of the data reveals that laser closure was cosmetically and histologically equivalent to the control groups, standard suture and tissue adhesive. It is reasonable to theorise that further refinement in the technology may see laser establish superiority over alternative closure methods.

2.3.2. Reflectance Confocal Microscopy

With the advent of agents such as imiquimod, cutaneous malignancies are now often managed with

topical treatments, without necessarily seeking recourse to post-treatment biopsy to confirm cancer clearance. Unfortunately, use of such agents often leads to erythema which can be misidentified as persistence of cancer. RCM has the potential to enable ‘virtual biopsies’ both in diagnosis (as previously discussed) as well as to confirm whether the cancer has been successfully cleared on completion of topical treatment [34]. Additionally, in cases where cutaneous malignancies have been excised, it is generally recommended that the scar is followed for any evidence of local recurrence [76]. However, there are certain malignancies such as amelanotic or lentigo maligna in which detection of recurrence may be challenging. This is another scenario in which RCM may assist in follow-up by allowing the periodic and non-invasive scanning of the skin surrounding the excision site for recurrence.

3. Conclusions

It is becoming increasingly apparent that technology plays an essential and growing role in dermatologic surgery. However, distilling all these elements into a paper reveals one inescapable fact: technology is merely a tool, best used by the discerning clinician. Patients do not just want medical technicians – they want doctors. First and foremost, patients want to feel that their doctor really, truly cares about them as individuals [77,78]. Thus, the close relationship forged between doctor and patient is the foundation upon which everything else, including cutting-edge science, stands. There is no synthetic substitute in this domain.

Cum Scientia Caritas – “compassion empowered with knowledge” [79].

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