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Overview

Surgical Innovation in Sarcoma Surgery

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Abstract

The field of orthopaedic oncology relies on innovative techniques to resect and reconstruct a bone or soft tissue tumour. This article reviews some of the most recent and important innovations in the field, including biological and implant reconstructions, together with computer-assisted surgery. It also looks at innovations in other fields of oncology to assess the impact and change that has been required by surgeons; topics including surgical margins, preoperative radiotherapy and future advances are discussed.

Key words: Innovation; oncology; orthopaedics; sarcoma; surgery

Statement of Search Strategies Used and Sources of Information

During the research for this article the authors used the following search terms: sarcoma, innovation, implant, non-invasive, allograft, vascularised fibula, endoprosthesis, silver, failure, aseptic loosening, computer navigation, three-dimensional (3D) printing, patient-specific instruments, preoperative radiotherapy, osteosarcoma margins, denosumab, MRfGUS, nanotechnology.

Surgical Innovation in Sarcoma Surgery

> If you always do what you always did, you will always get what you always got.
>
> Albert Einstein

Innovation is a double-edged sword in medicine and surgery, in particular. The Hippocratic Oath to 'do no harm' is stifling for innovation, as not all ideas will produce better results. In cancer surgery, this adage applies even more, where the consequences of failure are greater for the patient and surgeon alike, tending to lead to conservatism. How can we improve techniques, results and integrate new technologies into our practice safely? Through the bedrock of preclinical and clinical research, in which, results are carefully analysed, limitations understood and then disseminated for peer review and debate.

Innovation comes in several forms in surgery. First, improving a well-known technique to produce better results. Second, introducing existing technological advances to help the surgeon deliver an operation more successfully or reliably. Finally, introducing a radically different way of doing something, which leads to better or more reliable results for the patient; this is the hardest innovation in surgery.

Sometimes surgical innovation is evolutional, where improvements to a technique, resection or reconstruction, happen gradually over time as results become clear. This implies that the results of new ideas require time to see if they are successful. Sometimes, innovation is reactionary to rapid changes in practice in the multidisciplinary care of cancer and as we move to an era of personalised medicine, 'one size does not fit all'.

Finally, innovations in the fields of basic science, chemotherapy, radiotherapy and radiology, although not surgical, may improve a surgeon's ability to deliver successful cancer operations and better patient outcomes. Some advances will make our results poorer or complications greater, but they are better for the patient, in terms of

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survival or local recurrence. As surgical scientists we should adapt and innovate to improve our results in this setting. Rather than just list a variety of 'cool new stuff', the authors have tried to explain how and why innovations occurred, their results and where future innovations may occur.

Innovation Through Evolution of Techniques

> How can I go forward when I don't know which way I'm facing?
>
> John Lennon

Through analysis and dissemination of results of favoured techniques or implant design for a surgical problem, it is possible to incrementally improve outcomes by adopting or refining successful techniques. Knowledge of past results is critical to estimate the future. Therefore, honest appraisal of results without ego is required to allow innovation.

Biological Reconstructions

Allograft bone has been used for several decades in orthopaedic oncology, being the main method of reconstruction for many regions [1–4]. Non-union, fracture or infection [3–6] were the main complications, resulting in early failure of the reconstruction, but if these were avoided, then long-term reconstruction survival was possible [2–4]. Osteoarticular allografts (diaphyseal and joint reconstruction) often failed with progression to osteoarthritis in the short to medium term and their use has dwindled in recent years [7,8]. Allografts require significant periods of non-weight bearing (median 9 months) [9] as the allograft unites to host bone. Several retrieval studies showed that, on average, only 20% of the allograft is completely viable several years from implantation, leaving the allograft vulnerable to late fracture and subsequent failure [10–12].

Vascularised Fibula Reconstruction

Following problems of delayed union, several authors have advocated the use of autografted vascularised fibula reconstruction, either alone or in combination with allograft [13–19]. The use of a vascularised fibula is attractive, as it is cheap, doubly available and can be used for reconstructions up to about 20 cm in length, but they require microvascular reconstruction, which requires lengthy surgical procedures and specialist surgical experience, not available in every centre. The vascularised fibula contains viable osteoblasts and, under Wolf's law, can hypertrophy under load and unite quicker than allograft. The use of autograft fibula alone requires supplemental fixation (often with external frames) while union and hypertrophy occurs, often for 6–12 months, to reduce the risk of stress fractures, which occur in 15% in most series, with total complications occurring in up to 50% [9].

Allograft Supplementation

Methods to reduce the risk of allograft fracture include supplementation with poly(methyl methacrylate) cement or the combined use of allograft with a core of autograft fibula (either vascularised or non-vascularised). A Canadian group have advocated the use of cement augmentation for long allograft reconstructions with a reduction in fracture rate from 29% to 0% [20].

Abed *et al.* [18] popularised the use of allograft combined with an inner core of autograft vascularised fibula, the 'hotdog' technique, this produced a primary union in 92%, a mean fibula union at 5.6 months and a stress fracture in 12%. The allograft protects the autograft while it hypertrophies and, therefore, standard fracture plates can be used for fixation. Recently the authors have been using a modified 'hotdog' technique with non-vascularised fibulae, leaving the periosteum of the fibula in the donor bed and thus dispensing with the need for microvascular anastomosis, reducing operative time, while maintaining an acceptable time to union (mean 21 weeks) and allowing the regrowth of a 'neo-fibula' in 40% of cases, especially in the paediatric population. This neofibula regrows from the residual periosteum (as the fibula grows via intramembranous ossification) and it can be used for further autograft in the future and may provide support to the lower leg, reducing the incidence of stress fractures compared with allograft alone or vascularised fibula [21].

Endoprosthetic Reconstruction

Due to the lack of allograft in some regions, the use of metallic endoprosthetic (EPR) reconstruction became popular, with very durable long-term rates of limb salvage. However, the rapid early return to function that EPRs allowed has to be tempered with the long-term risks of infection, aseptic loosening and structural failure [22–31].

Custom and Modular Implants

The use of metallic replacements for sarcomas in or around major joints is now well established [22–31]. The functional results show that, on average, the patients can achieve acceptable function (about 80% of normal) and the long-term limb salvage is good, with only 16% of patients undergoing a secondary amputation at 30 years from diagnosis [22]. Traditionally, EPRs were custom made for the patient, a process that would take 4–12 weeks depending on the complexity of the reconstruction. However, implant manufacturers have now designed modular prostheses for all major joints (hip, knee, elbow, shoulder and pelvis), which are available 'off the shelf' and can be assembled at the time of surgery. These are particularly useful for patients who require urgent surgery, such as those with pathological fractures. Newer designs of implants, which take better into account joint biomechanics, have led to significantly improved outcomes. The proximal humerus EPRs are a good example, where, due to the lack of