The future of MSK interventions

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Interventional radiology has become so successful that it is easy to forget that it is a relative newcomer. Prior to 1980, arthrography was the only musculoskeletal intervention that was performed in most radiology departments.

Arthrography is an old procedure, first introduced in 1905 when air was used as the injected contrast agent [1]. Positive contrast was introduced three decades later, and the introduction of fluoroscopic control took several decades more. Members of the society made significant contributions to the development of arthrography. One of the pioneers in this work was Dr. Robert Frieberger of the Hospital for Special Surgery (New York).

Percutaneous bone biopsy is also an old procedure, although it was largely the province of orthopedic surgeons for many years. Invention of the trephine needles (such as the Ackerman needle and the Craig needle) in the late 1950s, and the recognition of the value of image guidance, made it feasible for radiologists to perform this procedure. By the late 1970s this was a common practice, although the limitations of fluoroscopic guidance meant that many anatomical sites were inaccessible or unsafe to biopsy.

Several factors have contributed to the advance of musculoskeletal interventions. Perhaps chief among them has been improved technology. Better visualization of anatomy yields more anatomical information. Spinal pain management was greatly improved when C-arm fluoroscopy became common in radiology practice. However, the axial plane is particularly valuable for procedure guidance, since it demonstrates the passage of a needle. The introduction of CT guidance in the 1970s, combined with improvements

in the ability to handle smaller tissues samples did much to expand the safety and effectiveness of percutaneous biopsy.

Radiologists have adapted to increasing capabilities by becoming more specialized. Greater specialization has fostered more detailed anatomical and functional knowledge and therefore greater confidence to undertake procedures that were previously thought to be hazardous or impossible. Finally, progress in materials and in biology has lead to more effective interventions. Therapeutic (as opposed to diagnostic) interventions have become increasingly important.

In some respects, the prospects for the future have never been brighter. Three major trends support the continued development and prosperity of the field.

Demographics

The population is aging, and growing heavier both in the US and abroad. Since many (perhaps most) musculoskeletal procedures are performed to address age-related deterioration of the locomotor system, these two facts ensure a growing number of patients.

The graying of the population has been accompanied by an increase in the prevalence of osteoporosis and the many problems that it causes, and the increasing obesity rates exacerbate the problem of aging joints. In response to these problems, both adults and children have been encouraged to exercise more. Whether more individuals are following this advice, or whether there are simply a larger number of relatively fit older adults, increasing numbers of sport-related injuries are being seen in all age groups.

In recognition of these facts, the first decade of the 21st century was proclaimed the bone and joint decade by the World Health Organization, and endorsed by 750 organizations throughout the world, including the United States.

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Hardware

Although the most rapid phase of innovation in diagnostic imaging may have passed with the maturing of CT and MRI, further improvements in the speed of image acquisition and in 3-D technology are changing the way that procedures are performed and making new procedures possible.

At the present time, true real-time 3-D procedure guidance is becoming widely available, although probably more accepted in operating rooms than in imaging suites. Robotic technology is also advancing rapidly, and finding its way into both settings. This technology may seem custom-made for the musculoskeletal system because of the high contrast afforded by mineralized structures, but adoption has been slowed by the problems related to needle deviation caused by uneven tissue densities.

Biological sciences

The pace of change is exhilarating. Almost every week brings a new level of sophistication to our understanding of the mechanisms of tissue injury and repair. Progress in basic science has led to a proliferation of new procedures and injectable agents, such as bone morphogenetic protein and percutaneous gene therapy.

Growth areas and problems related to shifting boundaries

Procedures for tissue ablation are fairly well established, although their potential has not been fully exploited. Thermal methods for tumor treatment (radiofrequency, cryoablation) have become important palliative [2] and in some cases curative modalities [3, 4]. A number of common clinical conditions appear to be good targets for this type of approach, but remain largely unexplored, awaiting future innovators. These include

- a) Morton's neuroma and other forms of traumatic neuroma [5, 6]
- b) Muscular arteriovenous malformations
- c) Pre-operative devascularization of tumors.

Further technical progress should lead to probes and electrodes that can produce ablative lesions with adjustable (but predictable) size and shape. Irreversible electroporation is a promising newcomer that is used to cause tissue destruction with electromagnetic fields but without resulting in heat. It uses rapid electromagnetic gradients to cause pores in cell membranes, leading to cell death [7].

Focused ultrasound is a form of thermal tissue injury cause by overlapped ultrasound beams. It can be guided by various imaging modalities, including MRI and diagnostic ultrasound and has recently been shown to be effective with bone lesions [8]. The use of pulsed RF fields offers promise as a less painful approach to many lesions, and also offers the opportunity to provide non-thermal treatments. [5].

At present, radiofrequency treatment for osteoid osteoma is the only one which constitutes the initial procedure of choice. Other percutaneous ablative therapies serve as secondary treatments for patients in which other avenues are not available, however, this is likely to change. With time, it will become clear which approaches are best for which situations.

Vertebroplasty and kyphoplasty have become fiercely controversial due to two publications in the *New England Journal of Medicine* in which they were found to be not superior to placebo [9, 10]. The findings in these studies are inconsistent with the experiences of many practitioners, who point to methodological flaws in the studies [11]. The situation is further complicated as the insurance industry and the advocates of cost control see an opportunity to deny payments [12].

However the specific issue of vertebroplasty is ultimately resolved, the use of injectable substances for filling defects and encouraging bone growth will continue to make progress. Injected BMP has been shown to enhance healing of segmental bone defects [13] and to speed the healing of fractures [14]. An interesting recent innovation is the combination of injected BMP-2 and bisphosphonate to simultaneously enhance bone formation and diminish resorption [15]. However, before BMP can be widely applied, a solution must be found for the heterotopic bone formation that it induces in soft tissues.

In addition, image-guided fracture fixation (with either internal or external devices) has made great advances. Applications for this approach will grow, as specialized tools and imaging techniques continue to progress. Although usually within the purview of orthopedics, there is no inherent reason that these procedures cannot be done by radiologists. The same reasoning could apply to various types of percutaneous surgeries that are already in use such as various forms of soft-tissue release, including treatments for epicondylitis and plantar fasciitis. At present, these are somewhat on the "fringes" of orthopedics. Over time, they will join the mainstream and will replace open or operative approaches.

Competition for percutaneous procedures is not new to radiology, as best exemplified in the area of vascular interventions. However, when this type of competition involves new and unproven procedures, it may have a particularly pernicious affect. Procedures inevitably proliferate

faster than they can be evaluated (coblation for nucleotomy, oxygen-ozone ablation, PRP injection, ultrasound-guided scar tissue lysis), and therefore physicians who wish to be the first to adopt new approaches run the risk of offering treatments of dubious merit, some of which will eventually be discredited [16].

Further, current reimbursement policies in the United States typically provide financial incentives to perform newer, more expensive procedures (for example, vertebroplasty kits sell for \$400, the newer kyphoplasty kits sell for \$3,400). By comparison, the newer kyphoplasty kits sell for \$3,400 [17]. This type of cost inflation gets compounded with self-referral and "entrepreneurial medicine" [18], as well as patient demand based upon wishful thinking. Further competition among medical specialists, as well as tightening of the fiscal belts will exacerbate this tendency, creating temptations to perform bizarre, untested, or trivial procedures [19, 20].

As radiologists continue to perform interventional procedures, they will be increasingly subject to the same sort of documentation requirements as their clinical colleagues, including procedure-specific accreditation and medical records completion. They may also find themselves to be the primary or only physicians managing a specific patient condition. Training programs will therefore need to teach radiologists how to manage a clinical practice including patient evaluation, record-keeping, patient follow-up, etc.

Perhaps all of these obstacles will cause radiology to lose or relinquish all of these procedures. However, I think that this is unlikely.

Radiology has certain strengths. For one thing, radiologists have a long history of performing percutaneous procedures and well-established training programs. Techniques have been carefully worked out and taught to residents and fellows in ways that surgical programs generally do not do. Hopefully, our specialty can produce convincing evidence that our procedures are done well.

Radiologists have generally been ahead of other fields of medicine in adoption of new technology. This trend continues into the present, with the creation of advanced methods of data mining. These tools can be used to demonstrate the appropriateness and efficacy of procedures.

Finally, and perhaps most importantly, are the cost-imperatives. New imaging equipment is expensive. Optimal use requires a physician whose work schedule is tied to the room- (i.e., a radiologist). In this respect, the radiologist and the equipment owner (usually a hospital) are natural allies. Perhaps the other musculoskeletal specialists (orthopedics, physiatry, rheumatology) will develop cadres of clinicians who wish to practice like radiologists, as has already happened in vascular surgery, in which case it may become

increasingly difficult to distinguish between an interventional radiologist and a minimally invasive surgeon.

Conclusions

I believe that the future of musculoskeletal procedures is bright with promise. We will need to work hard and creatively to maintain collegial working relationships with other specialties. We must learn to address and satisfy the expectations that come with greater patient care responsibilities, and above all, we must support innovations that are in the best interest of our patients.

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