PUTTING IT ALL TOGETHER

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The natural history of the asymptomatic focal chondral lesion is not known. We do know that even the most minimally invasive surgical treatment is potentially fraught with problems. Therefore, as we strive to "first do no harm," small incidental chondral defects should probably be treated with benign neglect in the absence of compelling clinical correlates. On the other hand, an argument can be made for the first-line treatment of lesions that range in size between 1 to 2 cm^2. This is based on the risk of defect progression and/or the potential of their incremental contribution to a patient's symptoms in light of the presence of other clinically relevant pathologic conditions (ie, meniscal tears). Careful consideration of the risk-benefit ratio may justify implementation of intervention at the index surgery.

Certainly, lesion characteristics (ie, size, location, depth, chronicity) combined with several patient-related factors such as age, obesity, genetic predilection, physical demands, expectations, prior surgical treatment, and associated pathologic conditions play a role in determining who will ultimately become symptomatic and which subsequent treatment option will be considered optimal. Once symptomatic, however, it is unlikely that these lesions will revert to a subclinical state without activity level modification or without some form of intervention. It is important to recognize that these lesions do not exist in a vacuum and are often associated with other local pathologic conditions. For example, if tibiofemoral malalignment or ligament instability exists, it must be corrected prior to or concurrent with any cartilage restoration treatment.

In the article in this issue prepared by Constance R. Chu, "Chondral and Osteochondral Injuries: Mechanisms of Injury and Repair Responses," we learn about the pathophysiology of articular cartilage repair in patients with symptomatic chondral disease. Many of these patients are relatively young and active, and hence activity modification is often considered unacceptable to them. However, because outcome data are in some cases incomplete or inconclusive regarding the appropriate treatment option, it is a challenge to advocate one type of intervention over another. Inevitably, these limitations lead the surgeon to choose a treatment option based upon a realistic synthesis of the surgeon's personal experience, local resource availability, and his or her unique understanding of the literature. Dr Chu's article assists the orthopedic surgeon in the decision-making process by integrating current knowledge with the information presented in this issue of *Operative Techniques in Orthopaedics*, "Management of Chondral Injury: Perspectives in the Millennium."

DIAGNOSIS AND EVALUATION

Because there remains much to learn about the biology and natural history of an isolated chondral injury or even the meniscal-deficient knee, sound surgeon judgment is essential to properly correlate the patient's symptoms and impairment to their presumed underlying disease. Because outcomes are highly dependent on the underlying disease, the more precise a diagnosis is preoperatively, the more meaningful informed consent will be for the patient. In that same line of thought, it is recognized that patient expectations largely influence final patient satisfaction, and thus the more that is known preoperatively about a patient's disease, the more the patients expectations may be tempered with reality. With this in mind, in addition to a comprehensive, pathology-specific physical examination, ancillary testing may be helpful to diagnose and determine appropriate treatment as the sensitivities of these tests continue to improve. The reader is encouraged to read the article in this issue "Imaging of Chondral Injury," by Timothy R. Hooper and Hollis G. Potter, for a concise overview of these techniques, which are instrumental in heightening our clinical sensitivity for these lesions.

OPERATIVE TREATMENT OPTIONS

Potentially, osteochondral defects respond favorably to repair, which is the subject of the article written by J. Robert Giffin, Christopher C. Annunziata, Tracy M. Vogrin, and Christopher D. Harner, "Primary Repair of Osteochondral and Chondral Injury."

Beyond primary repair, nonprosthetic arthroplasty treatment options for focal chondral defects can be described as palliative, reparative, or restorative. Palliative treatment includes arthroscopic debridement and lavage, which often provides short-term symptomatic relief. Technologic advances using radiofrequency devices have recently become popular in an effort to stabilize grade II and III chondromalacia. Great caution must be shown when any energy is applied to chondral tissue in view of the current concern with the use of non–temperature-controlled heat (where there is also significant risk for damage to the subchondral bone). This collateral damage may not be apparent for some time and must always be kept in mind. Currently, the subject invokes considerable contro-

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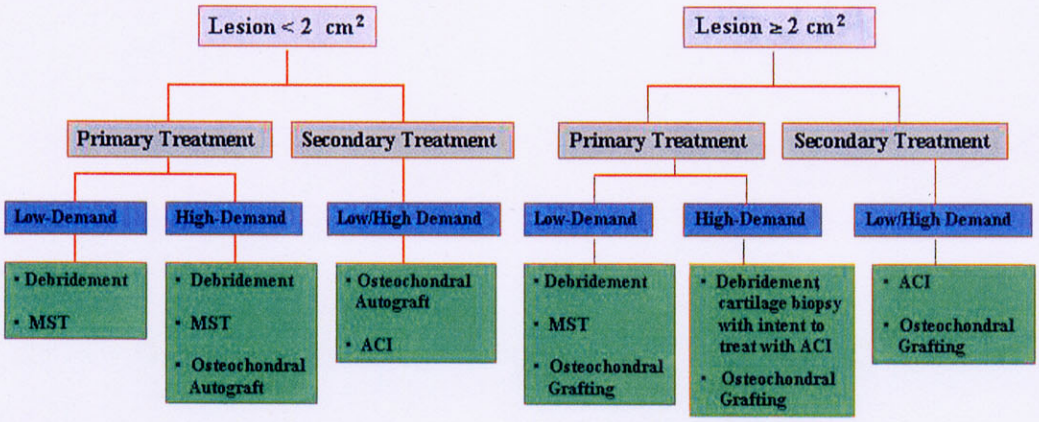

Fig 1. Composite treatment algorithm for the management of the symptomatic focal chondral defects of the femur. MST, marrow stimulating technique (ie, microfracture, abrasion arthroplasty, drilling); ACI, autologous chondrocyte implantation; osteochondral grafting, osteochondral autograft or fresh osteochondral allograft.

versy. We are fortunate to have a comprehensive review by Ryland B. Edwards and Mark D. Markel in their article entitled "Radiofrequency Energy Treatment Effects on Articular Cartilage."

Reparative treatment includes marrow-stimulating techniques (MSTs) that create scar cartilage or fibrocartilagenous repair tissue. This is the subject of the articles written by Jack M. Bert entitled "Abrasion Arthroplasty" and the article by Thomas J. Gill and John D. MacGillivray entitled "The Technique of Microfracture for the Treatment of Articular Cartilage Defects in the Knee."

Restorative techniques are reviewed by Andrew S. Levy in "Osteochondral Plugs: Autogenous Osteochondral Mosaicplasty for the Treatment of Focal Chondral and Osteochondral Articular Defects," by John Garrett and Jeffrey Wyman in "Operative Technique of Fresh Osteochondral Allografting of the Knee," and by Brian J. Cole and Mike D'Amato in their article, "Autologous Chondrocyte Implantation." As an informal summary, an updated technique atlas is provided by Mark D. Miller and Brian J. Cole entitled "Atlas of Chondral Injury Treatment." For simplicity, the final algorithm is also presented within this article.

THE TREATMENT ALGORITHM

The treatment of symptomatic chondral lesions is not currently amenable to a menu-driven decision-making process, and thus there is inherent overlap between treatment options. Figure 1 is meant to provide an overview of the surgical-decision tree currently available to treat symptomatic chondral lesions. It embodies the indications and results presented within the various articles in this issue. It is important to stress the tremendous complexity inherent in this process. Because multiple options often exist for similar lesions, the listing of procedures is such that there is no specific endorsement of one option over another. Optimally, a simplified approach to the treatment of symptomatic chondral lesions would be predicated on defect size (Fig 2) and previous treatment rendered for the problem. However, as previously indicated, other lesion- and patient-specific factors are critical to the decision-

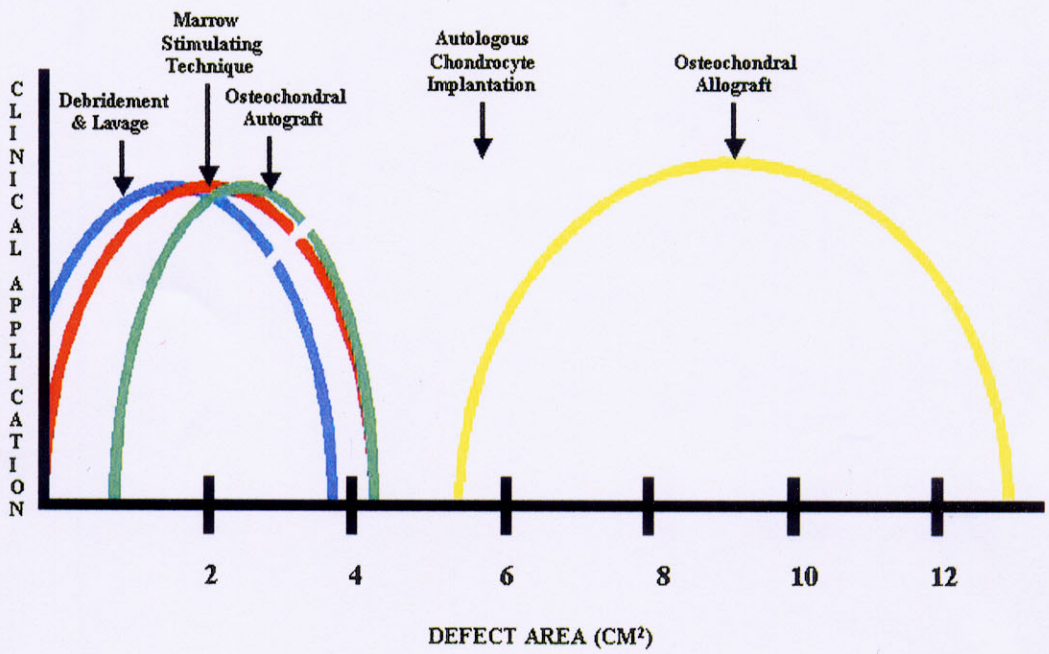

Fig 2. Phase shift diagram emphasizing overlapping indications for treatment options when size alone is considered. The complexity of decision making is only partially embodied by size considerations and must take into account primary or secondary treatment, defect location, and the principles of demand matching.

making process, and over simplification may lead to suboptimal results in several instances. The reader should be apprised that this algorithm is evolving and in all likelihood may look considerably different over time as clinical and basic research data fill in the gaps. Prospective comparative trials are underway for some options to help better define their indications. However, the complexity of the decision-making process, the spectrum of morbidity associated with differing treatment options, economic considerations with demand matching, physician access to procedure-specific resources, and patient demands may make randomized, prospective, comparative trials in each instance nearly impossible to accomplish.

Chondral Lesion Location

Most commonly, the focus of treatment is directed toward symptomatic lesions located within the weight-bearing surface of the femoral condyle. Treatment options for the femoral trochlea and patella exist but have fewer numbers of treated cases for review. Similar to tibiofemoral malalignment, concomitant treatment of patellofemoral malaligment is a necessary component of the treatment algorithm. Treatment options available for the tibia remain particularly challenging and are addressed to a limited extent within relevant articles.

Lesion Containment

As a subset of lesion location, containment is important. When treatment is for less than a full-thickness defect, the containment allows for a "template" to judge the height of restoration necessary. In addition, these "pillars of normal cartilage" carry load during the protective phase of implant maturation and remodeling. At times, the existence of these margins of normal tissue may be a more important factor for controlling patients' symptoms.

Chondral Lesion Size

Defect size is a key factor in determining treatment for symptomatic chondral lesions in any location. Results from all procedures used to treat full-thickness chondal injuries tend to be analyzed and presented in part by defect size. Unfortunately, recommended size boundaries vary according to surgical technique, surgeon, and the type of statistical analysis performed. The relevance of defect size is not absolute. For example, the size of the defect itself may be less important than the defect size relative to the overall surface area of the weight-bearing condyle. This factor may relate to containment and its protective potential. Similarly, as previously mentioned, factors leading to disease progression are numerous and complex. Finally, outcomes based on size only are limited and must be considered in the context of patient- and physician-specific factors, including the concept of demand matching discussed later. Accordingly, a "soft" cutoff of 2 to 3 cm^2 has been chosen but will certainly vary depending upon the surgical procedure chosen.

Some generalizations can be made based on defect size. Smaller lesions (ie, less than 2 to 3 cm^2) may be amenable to several treatment options including arthroscopic debridement and lavage, MSTs, osteochondral autografting, and autologous chondrocyte implantation (ACI). As the size of the lesions increases, (ie, greater than 2 to 3 cm^2) the limits of osteochondral autografts are approached. Osteochondral allografting may become a more viable option, especially when defects are associated with subchondral bone loss. Additionally, the success of first line treatment such as arthroscopic debridement and lavage and MSTs becomes less likely to be long lasting and thus, ACI may be considered a viable treatment option for larger lesions. Decision making is also guided by whether the treatment is primary or secondary and by patient physical demand levels.

Primary Versus Secondary Treatment

There is increasing acceptance that some treatment methods, while notably effective, may offer only short- or medium-term symptomatic relief. Thus, not uncommonly, patients with symptomatic chondral lesions may require revision or salvage surgery in an effort to further control symptoms. Although the results of some techniques used as a primary treatment option are considered limited, there is an even greater paucity of literature supporting the use of the same procedure twice (ie, as secondary treatment) in a scenario where it had already failed as the primary procedure. Appreciating this added complexity inherent in the decision-making process illustrates the importance of maintaining "bridges" for future treatment options.

The relative disadvantages to performing a specific primary procedure are even more confusing. That is, certain primary procedures may compromise a potential secondary procedure (when necessary if the primary procedure fails). Intuitively, with arthroscopic debridement and lavage, whether performed as a primary or secondary treatment option, one would expect a negligible effect on the outcome of future treatment options. Alternatively, penetration of the subchondral bone plate (as in MST procedures) may lead to intralesional osteophytes and increased subchondral bone stiffness and a vascular base. Although this result may have a negligible effect if the secondary treatment option includes osteochondral grafting, it may have a more significant and negative impact on the results following ACI or other future forms of cellular manipulation. On the other hand, it is important to avoid articular cartilage biopsy without the specific intention to treat a particular patient with ACI because of the significant economic implications. It must be understood that because there are insufficient data to make unique treatment recommendations in many instances, the algorithm remains broad and generalizes to treatments considered likely to be more useful as a primary or secondary option. Secondary treatment options are typically limited to ACI and osteochondral grafting. To date, the absolute size limits for osteochondral autografting have not been established, but the inventors of these procedures are urging a cautious approach.

Demand Matching

There is great potential for surgeons interested in cartilage restoration to borrow from the total joint surgeon's approach to prosthetic selection. That is, there is a potential

for demand matching of specific cartilage restoration techniques to a patient's specific needs. Just as all patients do not require the same "state-of-the-art" or expensive prosthesis for their joint replacement, all patients may not require a "state-of-the-art" cartilage restoration technique. In certain patients of lower demand, fibrocartilage repair tissue formed following MSTs may be an acceptable solution leading to symptom reduction. Alternatively, patients of higher demand may require higher grade tissue and alternative options, such as ACI or osteochondral grafting to reduce symptoms. If 2 procedures offer the same outcome and durability over the expected life of the patient, then intuitively, selecting the most cost-effective solution for both the patient and society is feasible. It is important to differentiate that this does not mean the cheapest procedure, but rather the lowest total lifetime cost of that procedure for that particular patient, including variables such as total surgical cost, time off work, and residual partial impairment once patients achieve maximal medical improvement as a result of their procedure.

Thus, in practice, demand matching is only possible with a complete understanding of the nature of the reparative response and its associated anticipated clinical benefit. For example, as a first-line procedure, MST may provide an excellent solution for small to moderate-sized lesions (of up to 3 cm^2) in minimally to moderately symptomatic patients whose physical demands fail to outstrip the symptom relief provided by fibrocartilage repair tissue. However, with increased size (area) of the lesion or with increased physical demand, tissue with more hyaline-like characteristics (ie, characteristics provided with ACI) may be required to tolerate increased compression and shear force. An alternative treatment for these patients who fail to respond to MSTs are osteochondral autograft procedures. However, current recommendations continue to evolve toward the treatment of smaller lesions (ie, up to 2 cm^2) because of concerns for donor site morbidity, limited supply of autologous grafts, graft subsidence, graft degeneration, and the lack of chondral integration. As an alternative to ACI, especially for larger lesions in patients of higher demand (ie, greater than 2 to 3 cm^2) where the limits of osteochondral autografts are reached, fresh osteochondral allografting may become a more viable option. Although the bone portion of the graft is slowly replaced through creeping substitution, the chondral tissue remains viable up to 17 years after implantation (Dr Allen Gross, personal communication, March 2000). Even more promising is the possibility for prolonged fresh tissue preservation, making fresh osteochondral allograft reconstruction truly an elective procedure with more time to evaluate the potential for infectious agents.

Promising research shows the ability to form hyaline-like cartilage in vitro. Theoretically, this cartilage tissue would be available for implantation off-the-shelf at the time of lesion identification. The future of cartilage repair is elegantly summarized with the elaborate work currently being performed at the University of Pittsburgh by Nobuo Adachi, Dalip Pelinkovic, Chang Woo Lee, Freddie H. Fu, and Johnny Huard and reported in the article entitled "Gene Therapy and the Future of Cartilage Repair." It continues to be very important to closely follow all outcomes in both the short- and long-term to help establish subtle differences between different cartilage repair techniques. It is useful to consider minimally invasive methods for assessing cartilage, ranging from and stiffness testing to biochemical measurements obtained from lavage, venipuncture, or even urinalysis. As outcomes emerge, the treatment algorithm must be revised accordingly, with an emphasis on matching the appropriate procedure to the appropriate patient with his or her inherent demand level.