A System for the Surgical Staging of Musculoskeletal Sarcoma

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Historically, an adequate surgical procedure has been the most effective means of treating the majority of primary musculoskeletal sarcomas, and amputation has figured prominently in the surgical armamentarium.[4,7,9,19,21,29,41] The recent evidence that certain chemotherapeutic agents may have significant anti-sarcoma activity[2,15,17,38] and coincident technical advances in irradiation therapy, radiographic localization, and reconstructive surgery have fostered enthusiastic interest in extremity-saving treatments. Almost all such treatments emphasize limb salvage as an alternative to amputation and are usually performed under a protective cloak of adjunctive chemotherapy, irradiation or immunoactive agents.[20,23,24,30,37,39] Since neither chemotherapy nor irradiation therapy alone has been shown to assure long-term local control of bulk disease, surgical intervention remains an essential step in the overall management of musculoskeletal sarcomas.[3,9,17,18,29] Questions concerning the magnitude and timing of the surgical procedure are as unanswered as those relating to the most appropriate use of the adjuncts themselves. Increasingly, the surgeon and his patient are confronted with a bewildering array of therapeutic options, the long-term outcomes of which are unknown.

These relatively rare sarcomas increasingly are distributed among a variety of treatment protocols in which multiple parameters differ. This trend necessitates interinstitutional cooperation if sufficient numbers of patients are to be available for the timely evaluation of treatments in clinical use.

Such cooperation and even effective interinstitutional communication are seriously hampered by the lack of uniform language, so that meaningful comparison of treatments is currently impossible. Prime factors include the lack of a consistent definition of the surgery performed and a serviceable surgical staging system encompassing bone and soft tissue. Standard terminology will assure that like and unlike treatments are appropriately compared. Although an effective staging system should serve all members of the multidisciplinary team, the biologic behavior of musculo-

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skeletal sarcomas suggests that the most useful staging system will articulate with the surgical procedure.

SURGICAL STAGING

A surgical staging system for sarcoma should:

1. Incorporate the most significant prognostic factors into a system which describes progressive degrees of risk to which a patient is subject.
2. Delineate progressive stages of disease that have specific implications for surgical management.
3. Provide guidelines to the use of adjunctive therapies.

Since its organization in 1959, the American Joint Committee for Cancer Staging and End Results Reporting (AJC) has undertaken responsibility for developing clinically useful staging systems for many kinds of cancer. The intent of staging is to designate "the state of a cancer at various points in time and is related to the natural course of this particular type of cancer." The purpose is to: "provide a way by which this information can be readily communicated to others; to assist in decisions regarding treatment; and to be a factor in judgement as to prognosis. Ultimately, it provides a mechanism for comparing like or unlike groups of cases, particularly in regard to the results of different therapeutic procedures." The AJC philosophy expresses the idea that "for most types of cancer, the extent to which the disease has spread is probably the most important factor determining prognosis and must be given prime consideration in evaluating and comparing different therapeutic regimens." To this end, the TNM system, where T designates the local extent of disease (often translated into size) of the primary tumor, N designates nodal extent, and M, metastatic extent, has been consistently used.[22,31] In addition to anatomic extent, the histopathologic analysis and grade of the tumor are other recognized prime determinants.[6,13,14,16,19,22,26,27,28,31–33]

The single attempt to develop a staging system for sarcomas of bone by the Task Force on Malignant Bone Tumors of the AJC failed to yield a satisfactory system. They recommended that institutions with access to large numbers of patients, consistency in management, and long-term follow-up undertake this task.[11] The staging system for soft tissue sarcomas proposed by the AJC in 1977[31] and the recent modification suggested by Hajdu[16] have, in our experience, been of limited value in the surgical management of soft-tissue lesions.[12,13,37]

A surgical staging system for musculoskeletal sarcomas is most logically accomplished by assessment of the surgical grade (G), the local extent (T), and the presence or absence of regional or distant metastases (M).

The sarcomas for which this system was designed are those arising from the mesenchymal connective tissue of the musculoskeletal system. Lesions derived from the marrow, reticuloendothelial tissue housed within bone and mesenchymal soft tissue, and the skull are not included in this system because their natural history, surgical management, and response to treatment are quite different. Thus, leukemias, plasmacytoma, lymphomas, Ewing's sarcoma, undifferentiated round-cell lesions, and metastatic carcinomas are excluded.

SURGICAL GRADE (G)

From the standpoint of surgical planning, neoplasms of any histogenesis are divided into two grades: low (G_1) and high (G_2). The majority of low-grade lesions may be managed with relatively conservative procedures while the high-grade lesions require more aggressive procedures to achieve the primary goal of a definitive oncologic surgical procedure—local control.[12,13,28,29] In general, low-grade lesions correspond to Broder's I or II and have a low risk for

metastases (<25%). Histologically, they are well-differentiated, have few mitoses, and moderate cytologic atypia. Their clinical course is marked by indolence. When they occur in bone, there is a tendency toward circumscription by reactive new bone.

High-grade lesions (Broder's III and IV) have a significantly higher incidence of metastases. They are characterized by poor differentiation, a high cell/matrix ratio, a high mitotic rate, necrosis, and microvascular invasion. Their clinical course is correspondingly marked by activity. Radiographically, the bone primaries are poorly marginated and have a permeated pattern. Angiographically, a reactive neovasculature usually rims the lesion.

The surgical grade may differ slightly from the purely histologic grade by consideration of clinical and radiographic features. Thus, the surgical grade may be weighted by the radiographic characteristics in chondrosarcoma, by the histologic appearance in fibrosarcoma, or by the clinical course in giant-cell tumor of bone. Usually there is good correspondence among the clinical, radiologic, and histologic findings.

The surgical grades (G) of a number of musculoskeletal sarcomas are given in Table 1. Each lesion ultimately is assessed on its own clinicopathologic features; not all parosteal osteosarcomas are low-grade,[1] nor are all intraosseous osteosarcomas high-grade.[40] In the absence of metastases, this method of separating lesions determines the stage: Stage I = G_1; Stage II = G_2. The stage is linked to surgical planning through providing information about what kind of surgical margin is required for definitive local control.

TABLE 1. Surgical Grade (G)

Low (G_1)	*High (G_2)*
Parosteal osteosarcoma Endosteal osteosarcoma	Classic osteosarcoma Radiation sarcoma Paget's sarcoma
Secondary chondrosarcoma	Primary chondrosarcoma
Fibrosarcoma, Kaposi's sarcoma Atypical malignant fibrous histiocytoma	Fibrosarcoma Malignant fibrous histiocytoma Undifferentiated primary sarcoma
Giant-cell tumor, bone	Giant-cell sarcoma, bone
Hemangioendothelioma Hemangiopericytoma	Angiosarcoma Hemangiopericytoma
Myxoid liposarcoma	Pleomorphic liposarcoma Neurofibrosarcoma Rhabdomyosarcoma Synovial sarcoma
Clear-cell sarcoma, tendon sheath Epithelioid sarcoma	
Chordoma	
Adamantinoma	
Alveolar cell sarcoma	Alveolar cell sarcoma
Other and undifferentiated	Other and undifferentiated

Surgical Site (T)

Just as the surgical grade is a measure of the overall biologic aggressivity of a lesion and indicates what kind of surgical margin is appropriate,[12,13,28,35] the anatomic extent or setting (T) indicates *how* the surgical procedure is most likely to be achieved[4,5,7,13,21,25,26,33,41] or even whether the desired margin can be achieved at all. The prime factor in determining *how* a surgical margin is accomplished is whether the lesion is within a well-delineated anatomic compartment or is diffusely infiltrating poorly demarcated adventitial planes and spaces. Therefore, the two stages are subdivided by whether the lesion is intracompartmental (A) or extracompartmental (B). Anatomic compartments have natural barriers to occult tumor extension: in bone, the barriers are cortical bone and articular cartilage; in joints, articular cartilage and joint capsule; and in soft tissues, the major fascial septae and the tendinous origins and insertions of muscles. In contrast, the ill-defined interfascial spaces and planes are limited only by loose areolar tissues that favor occult microextension. Because major neurovascular bundles lie in these interfascial extracompartmental tissues, a lesion involving these structures is by definition extracompartmental.

Both lesion size and its physical distance from vital structures are related to compartmentalization, but they are not determinants in surgical planning.[33] Although the larger lesions are more likely to become extracompartmental, neither large intracompartmental nor small extracompartmental lesions are unusual. Similarly, a lesion may be separated by only a few millimeters from a major nerve or vessel and yet be contained by a fascial septum that provides an adequate plane of dissection without sacrifice of the adjacent structures. Because satellite micronodules are routinely found in the pseudocapsular and reactive zones about all sarcomas, these zones must be considered an integral part of the lesion. Whether or not the lesion and its reaction is contained within a well-defined anatomic compartment more accurately indicates the feasibility of a local procedure than does the size or proximity to vital structures.[13]

The various surgical compartmental sites (T) are listed in Table 2. The left hand column lists the defined anatomic compartments: intraosseous, intra-articular, subcutaneous, paraosseous, and intrafascial. The skin and subcutaneous tissues are designated as an anatomic compartment because the deep fascia is a barrier to direct extension. In the same sense, the potential paraosseous space is a compartment; a lesion that has neither invaded the underlying bone nor penetrated the overlying muscle is intracompartmental. If a paraosseous lesion invades either the underlying bone or overlying muscle, it is extracompartmental.

Extracompartmental anatomic sites are listed in the right hand column of Table 2. A lesion is extracompartmental if it arises in these tissues or if it secondarily extends into them from an original intracompartmental site. Thus, a synovial sarcoma arising in the popliteal space is extracompartmental; an osteosarcoma of the femur extending into the quadriceps muscle is extracompartmental; and a fibrosarcoma of the quadriceps invading bone is extracompartmental. A superficial lesion which penetrates the deep fascia is extracompartmental, as is a deep lesion when it penetrates the fascia and becomes superficial. An intraosseous lesion that lifts periosteum from cortical bone or an intra-articular lesion that penetrates a joint capsule is extracompartmental. Surgical manipulation of a lesion without complete removal of the lesion places any tissue planes exposed to the lesion or postsurgical hematoma at risk for subsequent recurrence. Thus, most intracompartmental lesions are converted to extracompart-

TABLE 2. Surgical Sites (T)

Intracompartmental (T_1)	*Extracompartmental (T_2)*
Intraosseous	Soft-tissue extension
Intra-articular	Soft-tissue extension
Superficial to deep fascia	Deep fascial extension
Paraosseous	Intraosseous or extrafascial
Intrafascial compartments	Extrafascial planes or spaces
Ray of hand or foot	Mid and hind foot
Posterior calf	Popliteal space
Anterolateral leg	Groin—femoral triangle
Anterior thigh	Intrapelvic
Medial thigh	Mid-hand
Posterior thigh	Antecubital fossae
Buttocks	Axilla
Volar forearm	Periclavicular
Dorsal forearm	Paraspinal
Anterior arm	Head and neck
Posterior arm	
Periscapular	

mental lesions by any surgical manipulation which does not completely remove the lesion.

Detailed pathologic examination of specimens and surgical observations have documented that a reliable preoperative distinction between intra- and extracompartmental involvement may be made by the appropriate combinations of history, physical findings, roentgenograms, tomograms, angiograms, computed assisted tomography (CAT) scans, isotope scans, and other specialized studies.

Regional or Distant Extent (M)

The presence or absence of metastases is the third major factor related to both prognosis and surgical planning. In sarcomas the common route of hematogenous metastasis to the lung and the less common regional metastasis to lymph nodes have the same ominous prognostic significance. They indicate the failure of local control, and the presence of either indicates little chance for prolonged survival.[9,33,42]

SUMMARY OF STAGING

Based on these considerations, a Surgical Staging System (SSS) that stratifies both bone and soft-tissue lesions by grade (G_1 or G_2), anatomic setting (T_1 or T_2), and metastases (M_0 or M_1) has been constructed. The stages are based upon considerations of grade and metastasis. The stages are subdivided into A and B based upon the compartmentalization of the lesion. The stages and their subdivisions are summarized in Table 3. Stage I comprises those low-grade lesions shown in Table 1 (G_1); Stage II, the high-grade lesions in Table 1 (G_2); and Stage III lesions, those with either regional or distant metastases (G_1 or G_2, M_1). Stages I (G_1, M_0) and II (G_2, M_0) are further subdivided by the intra- (T_1) and extracompartmental (T_2) settings shown in Table 2. Thus, Stage IA is a low-grade, intracompartmental lesion with no regional or distant metastases (G_1, T_1, M_0); Stage IB is a low-grade, extracompartmental lesion without metastases (G_1, T_2, M_0); Stage IIA is a high-grade, intracom-

TABLE 3. Surgical Stages

Stage	*Grade*	*Site*
IA	Low (G_1)	Intracompartmental (T_1)
IB	Low (G_1)	Extracompartmental (T_2)
IIA	High (G_2)	Intracompartmental (T_1)
IIB	High (G_2)	Extracompartmental (T_2)
III	Any (G) Regional or distant metastasis	Any (T)

partmental lesion free of metastases (G_2, T_2, M_0); Stage IIB is a high-grade, extracompartmental lesion without metastases (G_2,T_2, M_0); and Stage III is of either grade and setting with metastases (G_1 or G_2, T_1 or T_2, M_1).

SURGICAL PROCEDURES

The articulation of the Surgical Staging System with surgical planning is accomplished by the link to a surgical procedure with margins that have predictable local recurrence rates.

Four types of margins based on the relationship of the surgical margin to the neoplasm and its pseudocapsular-reactive zone are recognized.[5,9,13,25,34–36] A descriptive summary of these margins and the anticipated residual disease is presented in Table 4. Since any of these margins may be accomplished by either a local procedure or an amputation, eight possible biologically significant surgical procedures result. These are summarized in Table 5 and detailed below.

1. Intralesional. An *intralesional* margin is accomplished by a procedure in which the dissection passes within the lesion. Macroscopic or microscopic tumor is left at the margins of the wound, and there is contamination of all the exposed tissue planes. Most commonly, local *intralesional* procedures are performed as a diagnostic incisional biopsy, by curettage of a presumably benign lesion, or by subtotal removal of a lesion to be managed by other means. An *intralesional amputation* is sometimes intended as a palliative procedure, but more commonly is done inadvertently because of occult microextensions of the lesion.

2. Marginal. A *marginal* margin is achieved by a procedure in which the lesion is removed in one piece. The plane of dissection is through the pseudocapsule or reactive tissue about the lesion, and when performed for malignant lesions, leaves microscopic disease at the margin of the

TABLE 4. Surgical Margins*

Type	*Plane of Dissection*	*Result*
Intralesional	Piecemeal debulking or curettage	Leaves macroscopic disease
Marginal	Shell out *en bloc* through pseudocapsule or reactive zone	May leave either "satellite" or "skip" lesions
Wide	Intracompartmental *en bloc* with cuff of normal tissue	May leave "skip" lesions
Radical	Extracompartmental *en bloc* entire compartment	No residual

* The plane of dissection used to achieve a particular margin is shown as well as the result of that margin in terms of residual lesion remaining in the wound.

TABLE 5. Surgical Procedures*

Margin	*Local*	*Amputation*
Intralesional	Curettage or debulking	Debulking amputation
Marginal	Marginal excision	Marginal amputation
Wide	Wide local excision	Wide through-bone amputation
Radical	Radical local resection	Radical disarticulation

* Classified by the type of margin they achieve and whether it is obtained by a local or ablative procedure.

wound in a high percentage of the cases.[4,5,9,33] As a local procedure, *marginal excision* is usually described as excisional biopsy or "shell 'em out" of a presumed benign lesion. *Marginal amputation* is usually done as either a palliative procedure, an attempted definitive procedure constrained by anatomic inaccessibility, or as an adjunctive procedure.

3. Wide. A *wide* margin is accomplished by a procedure in which the lesion, its pseudocapsule and/or reactive zone, and a surrounding cuff of normal tissue are taken as a single block. The plane of dissection is entirely through normal tissue but within the involved compartment. No effort is made to remove the entire length of involved muscle from origin to insertion or bone from joint to joint. The local wide procedure probably corresponds to what is referred to as "wide local excision," "*en bloc* excision," and "radical *en bloc* excision." A wide margin is definitive surgical management for Stage I lesions and can usually be accomplished by a local procedure for IA lesions.[12,13] Because Stage IB lesions usually involve some combination of bone, soft parts, and neurovascular structures, amputation is more likely to be required.

4. Radical. A *radical* margin is achieved by a procedure in which the lesion, pseudocapsule, reactive zone, and the entire muscles or bone involved are removed as one block. Longitudinally, the plane of dissection goes through or beyond the joint proximally and distally to the bone involved and through the tendinous origin and insertion of involved muscles. Transversely, the dissection passes beyond the major fascial septa of the involved soft tissue compartments or beyond the periosteum of intraosseous lesions. A radical margin does not necessarily imply a greater distance from the lesion to the margin of the wound than a wide margin. A margin on the other side of the intermuscular septum of a lesion in the vastus lateralis will constitute a radical margin but may be considerably closer than a wide margin achieved by amputation. A radical margin is definitive for Stage II lesions. A *radical local resection* can often be done for a Stage IIA lesion. If a lesion involves more than one compartment, or extends into or arises in the extracompartmental planes or spaces, compartmental containment is lost, and a radical margin is usually not attainable with a local procedure. Thus, *radical amputation* is usually carried out to achieve a radical margin in Stage IIB lesions, and it often requires a disarticulation or amputation proximal to the joint in question. These various procedures are illustrated diagramatically in Figures 1 and 2.

A total myectomy for a lesion within a single muscle may be either a wide local excision or a radical local resection, depending upon the muscle involved. If the muscle also constitutes a compartment, *i.e.*, the deltoid, then myectomy accomplishes a radical local resection. If the muscle is one of several muscles separated by loose areolar tissue within a large fascially contained compartment such as the rectus femoris, then myectomy is radical in the longitudinal sense but only wide in the transverse sense and is, by definition, a wide local excision.

APPLICATION

The utility and general applicability of this surgical staging system has been evaluated in two quite different situations: (1) intramurally by the University of Florida musculoskeletal oncology service, and (2) extramurally by an interinstitutional pilot study conducted by the Musculoskeletal Tumor Society.

The intramural evaluation involved patients treated on the musculoskeletal oncology service at the University of Florida since 1959. The service has well-established patient referral patterns, effective mechanisms for patient follow-up, and a consistent, well-defined surgical philosophy. A great deal of prospective primary observational data have been collected since 1959 and is stored in computers. Histogenic classification and grading have been done prospectively since 1974. Cases treated prior to 1974 have been retrospectively reviewed and graded, allowing reclassification along the lines of new histogenic concepts. The surgical grade, site, and stage were estimated preoperatively for surgical planning. The final stage was assigned after pathologic review of the surgical specimen. Two-hundred-fifty-eight cases form the basis of the intramural evaluation of the staging system.

The extramural evaluation of the system was done among 13 institutions (M. D. Anderson Hospital, SUNY–Buffalo, UCLA, UCSF, Case Western Reserve, University of Chicago, University of Iowa, Massachusetts General Hospital, Mayo Clinic, Memorial Hospital for Cancer–New York, University of Miami, University of Minnesota, and Rizzoli Institute of Orthopaedics, Bologna). Many of the participants are established investigators with extensive experience in the management of musculoskeletal neoplasms. The spectrum of their surgical philosophies ranges from conservative to highly innovative. These 13 institutions each have their own pathologists, referral patterns, methods of follow-up and mechanisms for handling data, and therefore represent a reasonable sample of the spectrum of musculoskeletal surgical oncology practice as it exists today.

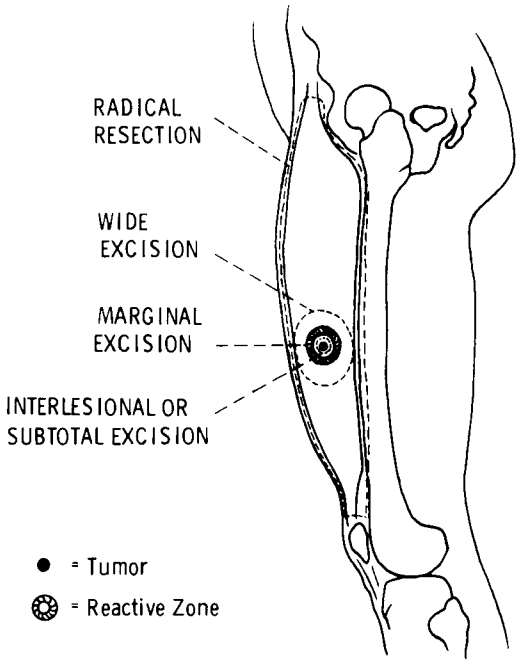

FIG. 1. The various local procedures are shown. The dotted lines indicate the plane of dissection and the amount of tissue removed to achieve the various procedures for a theoretical lesion within the anterior compartment of the thigh. Similar types of procedures may be done for bone lesions.

Each participant was mailed a questionnaire along with a précis of the staging system (Project Manager, Michael Simon, University of Chicago), and asked to retrospectively stage and submit ten consecutive cases of musculoskeletal sarcoma personally treated since 1970. The only restrictions were that the cases have a minimum two-year follow-up period. Patients could be entered without regard for treatment. This diverse group contributed 146 cases. Difficulty in utilizing the system was

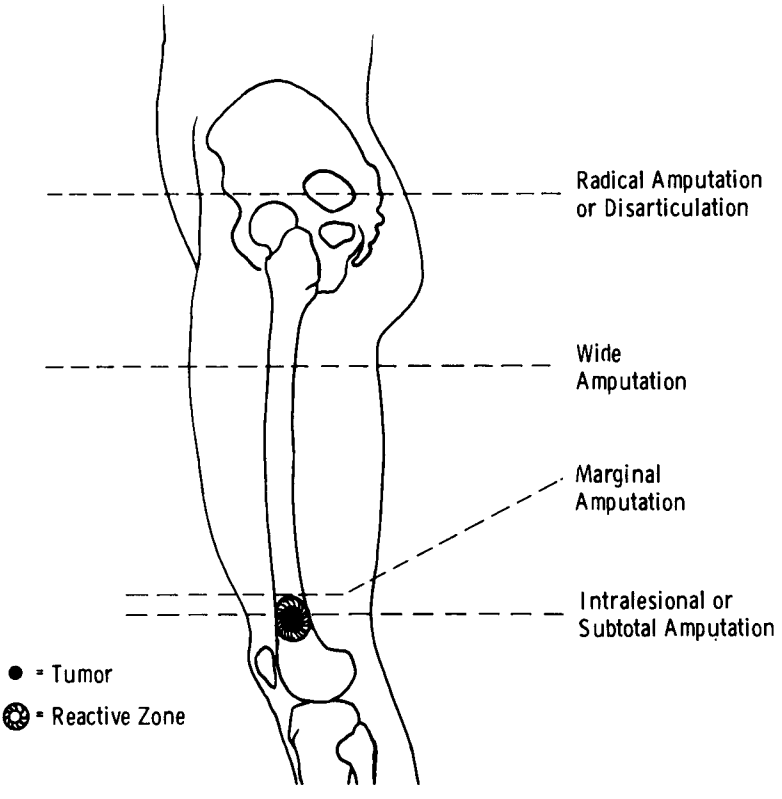

FIG. 2. The various types of amputations are shown for a theoretical lesion of the distal femur. Similar types of amputation may be done for soft-tissue lesions.

reported in 5.5% of cases, almost all problems being related to compartmentalization. Seven cases (5%) were excluded from analysis because of insufficient data. Bookkeeping errors were detected and corrected in 2.5% of the responses. The remaining 139 cases were studied.

Because of the limited amount of data in the extramural group, the survival probabilities were calculated by the method of Cohen for censored data.[10] The intramural data sets were analyzed both by the method of Cohen and by methods using absolute numbers of patients at risk for the time intervals studied.

RESULTS

The histogenic distribution for the total 397 cases is shown in Table 6, and the distribution by stage in Table 7. The histogenic distribution is comparable to other large series with the exception of the relative preponderance of malignant fibrous histiocytoma. There is a modest preponderance of bone lesions and a decided preoponderance of high-grade lesions.

The probability of survival as a function of stage for the extramural and intramural data sets is compared in Figure 3. The probability of survival by Cohen's method for the extramural group is no different from that of the intramural group (Fig. 3,A *vs.* Fig. 3,B). Moreover, it makes no difference whether the intramural data analysis is censored or based on absolute survival rates (Fig. 3,B *vs.* Fig. 3,C). This serves to validate the thesis that analysis of censored data provides a satisfactory estimate of the probability of survival and permits the combining of data for further analysis.

TABLE 6. Histogenetic Distribution

Diagnosis	Bone		Soft Parts	
	MSK	UF	MSK	UF
Chondrosarcoma	30	28	0	2
Chordoma	4	2	0	0
Clear-cell sarcoma	0	0	1	4
Fibrosarcoma	3	1	2	4
Liposarcoma, myxoid	0	0	6	12
Liposarcoma, pleomorphic	0	0	1	3
Malignant fibrous histiocytoma (MFH)	5	22	13	42
Neuroepithelial sarcoma	0	0	0	5
Classic osteosarcoma	43	40	0	0
Osteosarcoma, other	6	8	2	6
Parosteal osteosarcoma	7	8	0	0
Pleomorphic rhabdomyosarcoma	0	0	2	5
Synovial sarcoma	0	0	8	16
Unclassified	0	4	1	22
Other	2	6	3	18
Total	100	119	39	139

MSK = Musculoskeletal Tumor Society
UF = University of Florida

The probability of survival as a function of stage for the combined group of 397 cases of bone and soft-tissue sarcomas is shown in Figure 4. At each year of survival, there is a significant difference between the probability of survival for each stage ($p < .01$). Patients with Stage I lesions are at low risk and differ from those with Stage II lesions ($p < .01$). The difference between IA and IB lesions is not significant. Patients with Stage II lesions are at high risk ($p < .01$). The difference between Stage IIA and IIB is significant ($p < .01$).

The combined data were separated according to bone ($n = 219$) or soft parts ($n = 178$) origin. The probability of survival as a function of stage for each of these primary sites is illustrated in Figure 5. There is no difference in the survival of bone and soft tissue lesions that are of comparable stage.

The SSS and AJC systems for soft-tissue lesions were compared. The interinstitutional study did not provide sufficient information to retrospectively stage their soft-tissue lesions by the AJC criteria, and the comparative data were drawn from the intramural group. The results of comparing 139 soft-tissue primary lesions are shown in Figure 6. From one to five years, AJC Stages IA and IB are congruent. AJC Stages IA, IB, and IIA together are roughly equivalent to SSS Stage I. The AJC IIB is similar to SSS IIA. AJC Stages IIIIA, IIIB, and IVA have considerable overlap at all periods of observation and their distinction is not meaningful. Together they are similar to SSS Stage IIB. The AJC IVB is comparable to SSS Stage III.

TABLE 7. Distribution by Surgical Stage (N = 397)

Stage	Bone	Soft Parts
IA	22	15
IB	48	33
IIA	10	31
IIB	123	86
III	16	13
Total	219	178

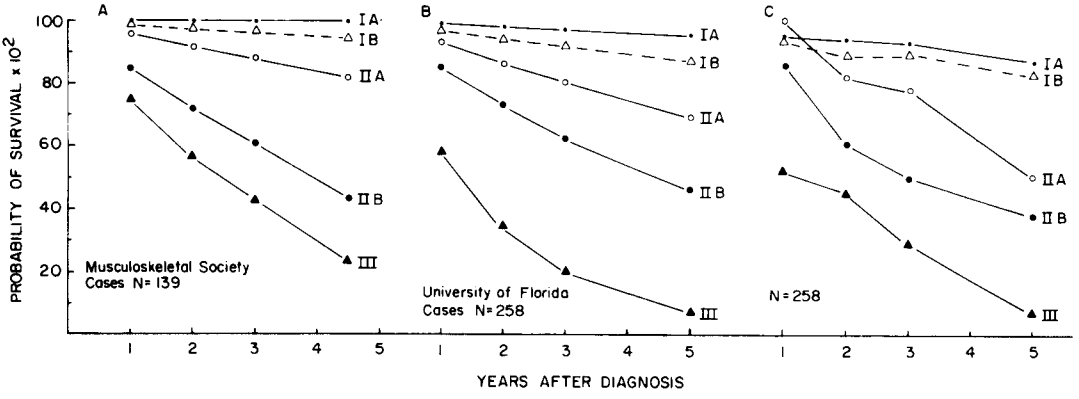

FIG. 3. The probability of survival for the extramural (A) and intramural (B) study group as well as the absolute survival for the intramural group (C) is shown by stages for a five-year period.

DISCUSSION

The Surgical Staging System in our experience has satisfactorily met the objectives. It has aided substantially in surgical planning and permits stratification of lesions in such a way that meaningful comparisons may be made between various treatment protocols.

The purpose of this article is not to describe what constitutes an appropriate surgical procedure in a given patient. Rather the purpose is to point out that in the design

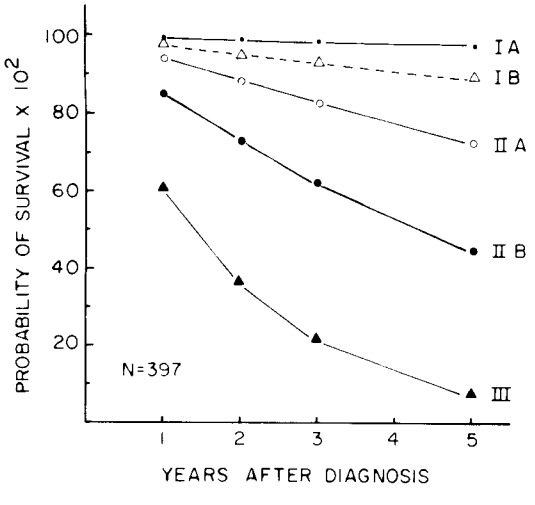

FIG. 4. The probability of survival by the various stages over a five-year period.

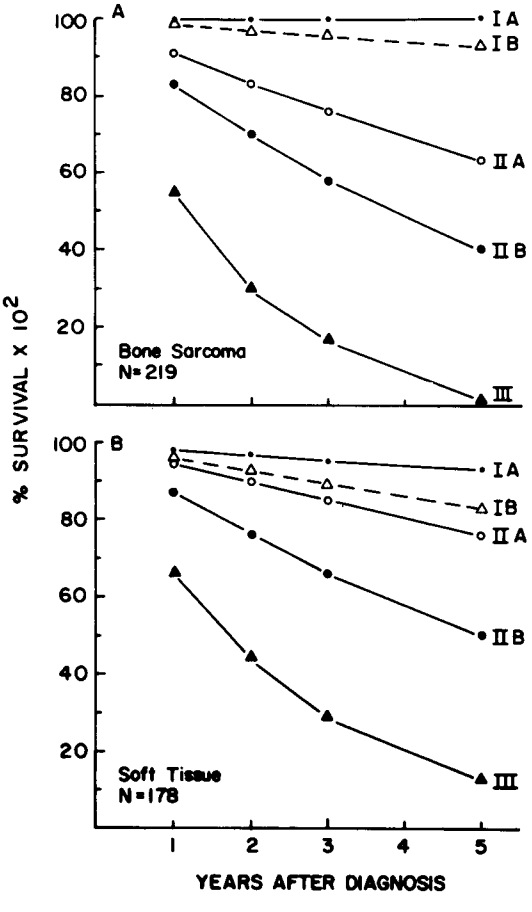

FIG. 5. The probability of survival by stages over a five-year period between bone (upper) and soft-tissue (lower) lesions.

of surgical procedures, the surgeon must meet two sometimes conflicting goals. One is local control of the lesion and the other is preservation of function. The Surgical Staging System, stratified on the basis of the risk factors associated with various surgical procedures, directly enhances treatment planning by permitting the formulation of alternative surgical plans in which the risk of recurrence for a given surgical procedure may be weighed against the benefit of retained function offered by each alternative. The patient's age, sex, expectations, and life style, coupled with the purpose of the procedure (palliative, diagnostic, curative, adjunctive), the surgeon's expertise, the availability of effective adjunctive therapy, and other facts lead to the final choice of operations.

The second objective is also well-served. In order to compare different methods of surgical treatment, the stage of the disease and adjunctive therapy must be the same. In order to compare the effectiveness of nonsurgical treatment, both the stage and the surgical procedure must be the same. It is inappropriate to compare the effectiveness of postoperative adjuvant chemotherapy between two patients with Stage IIB osteosarcoma when one has had a marginal local excision and the other a radical disarticulation. It is equally inappropriate to compare the effectiveness of postoperative irradiation therapy in synovial sarcoma when one patient had a Stage IA lesion with a wide local excision and the other had a Stage IIB lesion with a marginal local excision. Since the definitive surgical procedure is the single most important therapeutic maneuver, both it and the stage of the lesion must be comparable in order to assess the effectiveness of non-surgical adjuvants.

The AJC system is a complex system with four tiers. The system is based on assessment of histologic grade (G_1, G_2, or G_3), size (T_1 or T_2), in some cases, histogenesis, regional metastasis (N_0 or N_1), distant

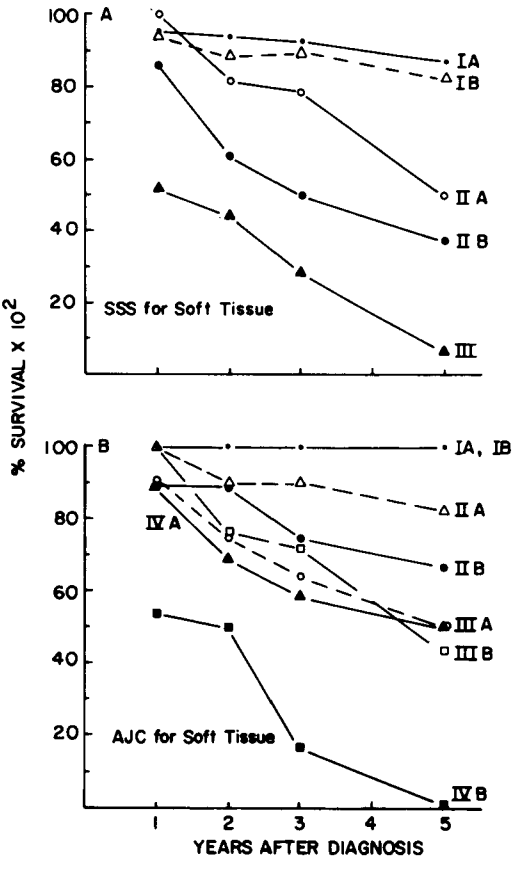

FIG. 6. The incidence of survival by stages over a five-year period. The upper figure shows the lesions staged by the Surgical Staging System while the lower figure shows the lesions staged by the AJC system for soft-tissue sarcomas.

metastasis (M_0 or M_1), and by the proximity of the lesion to neurovascular structures and bone. Although it has the merit of taking into account that histologic grade is a prime factor in the assessment of risk in soft-parts sarcoma, the proposal incorporates a number of conceptual premises that make its clinical use awkward:

1. Forty-seven per cent of the 1215 tumors upon which their proposal rests were located in the head and neck, retroperitoneum or other surgically inaccessible site. These lesions present such a different problem clinically, biologically, and surgically

that they should not be grouped with lesions of the extremities for analysis.

2. The division of sarcomas into three histologic grades is a histologic nicety. Although it is likely to have great appeal to the pathologist, it has little to offer the surgeon in terms of surgical guidance because there is no "middle" surgical procedure.

3. The T designation (local extent) is represented by lesion size. We believe that lesion size has prognostic significance that is a complex composite of anatomic setting, growth rate, and time to physician intervention. Since neither growth rate nor time to diagnosis can be quantitated, this variable in the AJC system would have more relevance if it reflected the extent defined by anatomic setting, *i.e.*, compartmentalization (or compartmental escape). The latter designation is more consistent with the natural biologic behavior of the sarcomas, and has meaning for the surgeon.

4. Appended to Stage III as IIIc are lesions with regional lymph node metastases. Lymph node involvement is so uncommon in the natural history of these lesions at the time of diagnosis as to not be worth a separate factor.[6,8,9,25,26,33,42] When this relatively rare phenomenon does occur, the prognosis is poor. If nodal metastases are given equal weight with other metastases, the surgeon knows that a contemplated procedure is likely to be palliative or must be supplemented with other treatment modalities to be curative.

5. "Gross involvement of a major nerve, artery, or bone" (T_3) is poorly defined, and the methods by which these judgments are to be made are not defined. Lesions with such involvement are assigned to a higher stage without regard for grade. Analysis of our soft-tissue sarcoma data by this method results in these Stage IVA lesions having a prognosis similar to AJC Stages IIIA and B lesions. Such involvement is a proper function of the anatomic setting (extent of the primary), and as such, does not require a separate category.

6. Lesions of certain histogenesis are assigned to at least Stage III because of their usual poor prognosis. This is a function of grade and should be treated as such. Occasional lower grades of these lesions do occur, and they should be staged accordingly.

The AJC system proposed for primary bone lesions is so complex that we have not retrospectively compared it with the Surgical Staging System. However, it is different from the AJC soft tissue system and if generally adopted would require the use of two complex systems that would not permit ready comparison between bone and soft-tissue sarcomas of the same histogenesis. Because definitive surgery is the primary treatment for sarcomas of both bone and soft tissue, and because the principles describing their biologic behavior and surgical procedures are the same for both groups, a common staging system for both groups would be more useful than two separate and different systems.

It is ironic that the essentials of the staging system proposed here were recognized by Quick and Cutler[28] over 50 years ago. They divided 75 tumors which they believed to be of neurogenic origin into three progressive histologic grades and correlated their microscopic observations with the clinical course and treatment. Their clinical rate of metastases reinforces our view that a simple division into high and low grade is practical and sufficient to define the risk of distant spread. Lesion size was not an important determining factor in survival but anatomic location and inadequacy of treatment were. They recognized the relationship between histologic grade and an adequate surgical procedure to patient survival. Their statement that "whereas wide local excision of the acellular fibrous tumors may result in a cure, this procedure is frequently followed by local recurrence and pulmonary metastasis in the highly cellular and malignant tumors (their Grades II and III)," is a precise statement of the principles of tumor surgery re-

capitulated at our institution.[13,28,36] They appreciated the occasional need for adjunctive therapies and attempted to elucidate factors in their appropriate use by comparing treatment results. The dilemma in treatment choices: "Tumors of the extremity in which amputation offers a chance of completely eradicating the disease present an important problem in treatment. The decision between amputation on the one hand and excision and radiation on the other is at times most difficult," is as unresolved now as it was then.

The Surgical Staging System for sarcomas of bone and soft tissues presented here is simple, clear cut, and has a high degree of compliance and accuracy. It is relevant to both surgical planning and end-result studies. It is quite clear that in comparing nonsurgical treatment protocols both the prognostic stage and the extent of the surgical procedure must be clearly defined and standardized before meaningful end-result studies can be made. The absence of a generally accepted staging system articulated with clearly defined surgical procedures has hampered the understanding of the proper role of various nonsurgical methods in managing musculoskeletal sarcomas. The surgical staging system and surgical definitions presented here form the basis for the ongoing interinstitutional studies currently being conducted by the Musculoskeletal Tumor Society.

SUMMARY

A surgical staging system for musculoskeletal sarcomas stratifies bone and soft-tissue lesions of any histogenesis by the grade of biologic aggressiveness, by the anatomic setting, and by the presence of metastasis. The three stages: I—low grade; II—high grade; and III—presence of metastases, are subdivided by (a) whether the lesion is anatomically confined within well-delineated surgical compartments, or (b) beyond such compartments in ill-defined fascial planes and spaces. Operative margins are defined as intralesional, marginal, wide, and radical, and relate the surgical margin to the lesions, its reactive zone, and anatomic compartment. The system defines prognostically significant progressive stages of risk which also have surgical implications. When the system is linked to clearly defined surgical procedures, it permits appropriate evaluation and comparison of the new treatment protocols designed to replace standard surgical treatment.

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REFERENCES

1. Ahuja, S. C., Villacin, A. B., Smith, J., Bullough, P. G., Huvos, A. G., and Marcove, R. C.: Juxtacortical (parosteal) osteogenic sarcoma. J. Bone Joint Surg. 59A:632, 1977.
2. Beattie, E. J., Martini, N., and Rosen G.: The management of pulmonary metastases in children with osteogenic sarcoma with surgical resection combined with chemotherapy. Cancer 35:618, 1975.
3. Beck, J. C., Wara, W. M., Bovell, E. G., and Phillips, T. L.: The role of radiation therapy in the treatment of osteosarcoma. Radiology 120:163, 1976.
4. Bowden, L., and Booher, R. J.: Surgical considerations in the treatment of sarcoma of the buttock. Cancer 6:89, 1953.
5. Bowden, L., and Booher, R. J.: The principles and technique of resection of soft parts for sarcoma. Surgery 44:963, 1958.
6. Broders, A. C., Hargrave, R., and Meyerding, H. W.: Pathological features of soft tissue fibrosarcoma. Surg. Gynecol. Obstet. 69:267, 1939.
7. Cantin, J., McNeer, G. P., Chu, F. C., and Booher, R. J.: The problem of local recurrence after treatment of soft tissue sarcoma. Ann. Surg. 168:47, 1968.
8. Castro, E. B., Hajdu, S. I., and Fortner, J. G.: Surgical therapy of fibrosarcoma of extremities. Arch. Surg. 107:284, 1973.
9. Clark, R. L., Martin, R. G., White, E. C., and Old, J. W.: Clinical aspects of soft-tissue tumors. AMA Arch. Surg. 74:859, 1957.
10. Cohen, A. C.: Progressively censored sample in life testing. Technometrics 5:327, 1963.
11. Copeland, M. M., Robbins, G. F., and Myers, M. H.: Development of a clinical staging system for primary malignant tumors of bone: a progress report. *In* Management of Primary Bone and Soft

Tissue Tumors, Chicago, Year Book Medical Publishers, Inc., 1977, p. 35.
12. Enneking, W. F., and Spanier, S.: Surgical staging of musculoskeletal tumors. Presented at the 47th Annual Meeting of the American Academy of Orthopaedic Surgeons, Atlanta, February, 1980.
13. Enneking, W. F., Spanier, S. S., and Malawer, M. M.: The effect of the anatomic setting on the results of surgical procedures for soft parts sarcoma of the thigh. Cancer (in press).
14. Evans, H. L., Ayala, A. G., and Romsdahl, M. M.: Prognostic factors in chondrosarcoma of bone: a clinico-pathologic analysis with emphasis on histologic grading. Cancer 40:818, 1977.
15. Gottlieb, J. A., Baker, L. H., Quagliana, J. M., Luce, J. K., Witecare, Jr., J. P., Sinkovics, J. G., Rivkin, S. E., Brownlee, R., and Frei, E. III: Chemotherapy of sarcomas with a combination of Adriamycin and dimethyl triazeno imidazole carboxamides. Cancer 30:1632, 1972.
16. Hajdu, S. I.: Pathology of Soft Tissue Tumors. Philadelphia, Lea & Febiger, 1979, p. 43.
17. Jaffe, N., Frei, E., Traggis, D., and Bishop, Y.: Adjuvant methotrexate citrovorum-factor treatment of osteogenic sarcoma. N. Engl. J. Med. 291:994, 1974.
18. Jenkin, R., and Derek, T.: The treatment of osteosarcoma with radiation: current indications. *In* Management of Primary Bone and Soft Tissue Tumors. Chicago, Year Book Medical Publishers, Inc., 1977, p. 151.
19. Lieberman, Z., and Ackerman, L. V.: Principles in management of soft tissue sarcomas. Surgery 35:350, 1954.
20. Lindberg, R. D., Martin, R. G., Romsdahl, M. M., and McMurtrey, M. J.: Conservative surgery and radiation therapy for soft tissue sarcomas. *In* Management of Primary Bone and Soft Tissue Tumors. Chicago, Year Book Medical Publishers, Inc., 1977, p. 289.
21. Lunseth, P. A., and Nelson, C. L.: Longitudinal amputation for the treatment of soft tissue fibrosarcoma. Clin. Orthop. 109:147, 1975.
22. Manual for Staging of Cancer, 1977, Chicago, American Joint Committee, p. 1.
23. Martin, R. G., Lindberg, R. D., and Russell, W. O.: Preoperative radiotherapy and surgery in the management of soft tissue sarcoma. *In* Management of Primary Bone and Soft Tissue Tumors. Chicago, Year Book Medical Publishers, Inc.,1977, p. 299.
24. Morton, D. L., Eilber, F. R., Townsend, C. M., Grant, T. T., Mirra, J., and Weisenburger, T. H.: Limb salvage from a multidisciplinary treatment approach for skeletal and soft tissue sarcomas of the extremity. Ann. Surg. 184:268, 1976.
25. Pack, G. T., and Ariel, I. M.: Principles of treatment of tumors of the soft somatic tissues. *In* Pack, G. T., and Ariel, I. M., (eds.): Treatment of Cancer and Allied Diseases, Tumors of Soft Somatic Tissues and Bone, 2nd edition. New York, Hoeber Medical Division, Harper and Row, 1964, VIII, p. 8.
26. Pack, G. T., and Ariel, I. M.: Fibrosarcoma of the soft somatic tissues. Recent Adv. Surgery 31:443, 1952.
27. Pritchard, D. J., Lunke, R. J., Taylor, W. F., Dahlin, D. C., and Medley, B. E.: Chondrosarcoma: a clinicopathologic and statistical analysis. Cancer 45:149, 1980.
28. Quick, D., and Cutler, M.: Neurogenic sarcoma, a clinical and pathological study. Ann. Surg. 86:810, 1927.
29. Romsdahl, M. M., and Ayala, A. G.: Surgical management of osteosarcoma. *In* Management of Primary Bone and Soft Tissue Tumors. Chicago, Year Book Medical Publishers, Inc., 1977, p. 137.
30. Rosen, G., Murphy, M. L., Huvos, A. G., Gutierrez, M., and Marcove, R. C.: Chemotherapy, *en bloc* resection and prosthetic bone replacement in the treatment of osteogenic sarcoma. Cancer 37:1, 1976.
31. Russell, W. O., Cohen, J., Enzinger, F., Hajdu, S. I., Heise, H., Martin, R. G., Meissner, W., Miller, W. T., Schmitz, R. L., and Suit, H. D.: A clinical and pathological staging system for soft tissue sarcomas. Cancer 40:1562, 1977.
32. Sanerkin, N. G.: The diagnosis and grading of chondrosarcoma of bone. Cancer 45:582, 1980.
33. Shiu, M. H., Castro, E. B., Hajdu, S. I., and Fortner, J. G.: Surgical treatment of 297 soft tissue sarcomas of the lower extremity. Ann. Surg. 182:597, 1975.
34. Simon, M. A., and Enneking, W. F.: The management of soft tissue tumors of the extremities. J. Bone Joint Surg. 58A:317, 1976.
35. Simon, M. A., Spanier, S., and Enneking, W. F.: Soft tissue sarcomas of the extremities. Surg. Annu. 11:363, (ed.) Nyhus, L., 1979.
36. Spanier, S., and Enneking, W. F.: Chapter 8: Musculoskeletal tissues. *In* Pierson, K. K. (ed.): Principles of Prosection. New York, John Wiley and Sons, 1980, p. 61.
37. Storm, F. K., Eilber, F. R., Mirra, J., and Morton, D. L.: Neurofibrosarcoma. Cancer 45:126, 1980.
38. Suit, H. D., Russel, W. O., and Martin, R. G.: Management of patients with sarcoma of soft tissue in an extremity. Cancer 31:1247, 1973.
39. Townsend, C. M., Jr., Eilber, F. R., and Morton, D. L.: Skeletal and soft tissue sarcomas: results of surgical adjuvant chemotherapy. AACR Proceedings 17:C–116, 1976.
40. Unni, K. K., Dahlin, D. C., McLeod, R. A., and Pritchard, D. J.: Intraosseous well-differentiated osteosarcoma. Cancer 40:1337, 1977.
41. Wanebo, H. J., Shah, J., Knapper, W., Hajdu, S. I., and Booher, R.: Reappraisal of surgical management of sarcoma of the buttock. Cancer 31:97, 1973.
42. Weingrad, D. N., and Rosenberg, S. A.: Early lymphatic spread of osteogenic and soft-tissue sarcomas. Surgery 84:231, 1978.