

Breast Sarcoma Beyond Resection: Reconstruction and Long-Term Survival

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Abstract

Background: Breast sarcoma resection can require extensive reconstruction. We examined reconstructive procedures, subsequent surgery and long-term survival in a breast-specific institutional cohort that included malignant phyllodes tumors.

Methods: We reviewed 26 records of breast sarcoma or phyllodes tumor. Twenty patients, including two with malignant phyllodes tumors, had dated tumor resections and entered the operative and survival analyses. Reconstructive procedures and subsequent operations were classified from operative summaries. Overall survival was estimated from the first recorded tumor resection using Kaplan–Meier methods, with sensitivity analyses addressing histologic composition and an incomplete follow-up date.

Results: The complete series included nine angiosarcomas, three phyllodes tumors and 14 other sarcomas. All 20 operative patients achieved R0 resection; median age was 55.0 years. Initial coverage used flaps in 13 patients, skin grafts in three and primary closure in one; the method was unspecified in three. Fourteen patients had a flap documented during their operative course. Six deaths occurred. Median follow-up estimated by reverse Kaplan–Meier was 15.0 years. Five- and ten-year overall survival were 82.0% (95% confidence interval 53.5–93.9) and 74.5% (44.9–89.8), respectively. Excluding dermatofibrosarcoma protuberans, ten-year survival was 68.1% (34.7–87.0). Recurrence annotations were present in six patients. Complete excision of the irradiated field could not be established from the operative summaries.

Conclusions: Frequent flap use and survival beyond a decade support considering long-term survivorship when planning breast sarcoma reconstruction. Histologic composition influences pooled survival estimates. Resection extent and reconstructive method require separate documentation to evaluate outcomes after irradiated-field excision.

Background

Breast sarcomas present an unusual reconstructive problem. Oncologic surgery may remove a large skin envelope, breast parenchyma or deeper tissues, while the subsequent clinical course can range from early recurrence to prolonged survival. Reconstruction therefore has to address the defect produced by tumor clearance and the needs of patients who may live for many years after treatment. Published breast-specific series remain heterogeneous in histology, treatment exposure and follow-up [1]. Phyllodes tumors add a related but distinct group of fibroepithelial neoplasms whose stromal component can behave aggressively; contemporary recommendations emphasize specialist pathologic assessment and coordinated breast and sarcoma care [2].

Previous reconstructive series describe autologous tissue, skin grafts and implants after breast sarcoma resection, with substantial differences in case composition and follow-up [3, 4]. Reporting the initial procedure alone gives an incomplete account of reconstructive care. Later operations may address

recurrent tumor, wound problems, additional coverage or elective refinement. Following these procedures alongside survival provides a more clinically useful description of the course after resection.

Our group has previously characterized outcomes in primary and secondary angiosarcoma and evaluated Sarculator and Memorial Sloan Kettering Cancer Center nomograms in this entity [5, 6]. Those studies addressed clinical risk and prognosis; the present analysis focuses on reconstructive procedures and long-term survival after breast sarcoma resection.

Radiation-associated angiosarcoma has made the relationship between oncologic resection and defect coverage particularly relevant. Resection of all or nearly all previously irradiated breast skin has been associated with improved disease-specific outcomes in retrospective data [7]. A recent technical series describes excision of the entire irradiated skin and soft-tissue field, followed by skin grafting or flap coverage [8]. Such resections can create defects that extend beyond the usual requirements of breast mound reconstruction [9]. However, the extent of the irradiated field removed is a distinct exposure that cannot be inferred from a mastectomy or flap label.

We examined a breast-specific institutional series to describe reconstructive methods, subsequent operations and overall survival over extended follow-up. All histologic groups were retained, with phyllodes terminology harmonized and radiation association recorded separately within angiosarcoma. The objective was to characterize reconstructive care across the observed course of disease.

Methods

Study design and population

This retrospective single-center study used an institutional case-level dataset from the Department of Plastic, Reconstructive and Hand Surgery and Sarcoma Center at BG University Hospital Bergmannsheil, Ruhr University Bochum, Bochum, Germany. The series comprised 26 patients with tumors originating in the breast, including sarcomas of the breast skin or deeper breast tissues and phyllodes tumors. Operations extending into adjacent thoracic structures were retained according to the breast origin of the tumor. The cohort did not include primary chest wall tumors. No tumor-size threshold was applied because systematic measurements were unavailable.

All 26 records contributed to the description of histologic composition. Twenty contained a dated definitive tumor resection and contributed to the operative and survival analyses. Their first recorded resections occurred between 1999 and 2025. Six records lacked a dated resection and were not assigned a surrogate time origin. Completeness of ascertainment of all eligible patients over the historical period could not be independently established from the case list. Reporting was organized according to the STROBE framework [10]. A reporting checklist and additional methodological details are provided in Additional file 1.

The study was conducted under the institutional sarcoma registry approval granted by the Ethics Committee of Ruhr University Bochum, Germany (approval no. 20-7126), in accordance with the Declaration of Helsinki.

Data sources and histologic classification

The dataset contained diagnoses, dates of birth, narrative operative summaries, recurrence annotations, death dates and last-status entries. The last-status entries included telephone follow-up verification where available, with the latest verification in September 2026. A verification date for an earlier death was not used as the death date. Patients without a recorded death were censored at their last documented evidence of being alive, rather than at the date of analysis.

Historical cystosarcoma phyllodes and explicitly malignant phyllodes diagnoses were combined as phyllodes tumors. The original indication of malignancy was preserved: two records explicitly stated malignant phyllodes tumor and one used the historical term without a documented grade. Both phyllodes cases included in the operative and survival analyses were malignant and were evaluated alongside the other breast sarcomas, with their histologic designation retained. All angiosarcomas were grouped together; radiation association was coded only when explicitly recorded. Its absence from the diagnosis field was not interpreted as evidence of a primary, non-radiation-associated angiosarcoma. Dermatofibrosarcoma protuberans (DFSP), chondrosarcoma, fibrosarcoma, leiomyosarcoma and sarcoma not otherwise specified (NOS) were retained as separate histologies.

The treating surgical team retrospectively confirmed final R0 status (microscopically negative margins) in all 20 operative patients; R0 was required for definitive reconstruction. Measured margin clearance and the timing of R0 achievement were unavailable. Original pathologic slides, complete operative reports and radiotherapy plans were not available for this analysis. Tumor size, grade, metastatic status at presentation, systemic therapy, resection dimensions and patient-reported outcomes were not systematically recorded. No values for these variables were inferred from the reconstructive method.

Reconstruction and operative classification

Initial defect coverage was defined as the first recorded coverage of the index breast defect, including linked procedures within 30 days of resection. Methods were classified as rectus abdominis flap, other flap, split-thickness skin graft, primary closure or unspecified soft-tissue coverage. Mesh reinforcement was recorded separately because it does not establish the method of soft-tissue closure. Transverse and vertical rectus abdominis myocutaneous flaps were abbreviated as TRAM and VRAM, respectively. Flaps recorded later in the operative course were also captured, without treating this later exposure as a baseline survival group.

Each recorded operation was assigned one principal category: tumor surgery, a separate reconstructive procedure, wound intervention, elective refinement, biopsy or unspecified indication. A procedure

combining tumor resection and reconstruction was counted once under tumor surgery, while its reconstructive component was retained in the reconstruction data. Early re-excision was not automatically classified as recurrence. Debridement and necrosectomy were considered evidence of a wound intervention; non-mention of a complication was not coded as an uncomplicated course. These categories describe the available operative record and do not represent prospectively ascertained complication rates.

Outcomes and statistical analysis

The primary time-to-event outcome was overall survival, measured from the first recorded definitive tumor resection to death from any cause. This origin was the first resection available in the dataset and was not assumed to be the first lifetime operation. A biopsy preceding definitive resection was excluded as a survival origin. Causes of death were unavailable, preventing estimation of disease-specific survival.

Kaplan–Meier estimates were accompanied by 95% confidence intervals calculated using Greenwood variance and a log–log transformation. Numbers at risk were displayed at clinically interpretable landmarks. Follow-up was summarized using the reverse Kaplan–Meier method [11]. An additional analysis excluding DFSP assessed the influence of histologic composition; it was a sensitivity analysis of a nested cohort, not an independent treatment comparison. No multivariable modeling or significance testing of reconstructive techniques was undertaken because only six deaths were observed and relevant confounders were unavailable.

One patient had a recurrence recorded only as October 2025, later than an exactly dated July 2025 operative/status entry. The primary analysis conservatively used October 1, 2025, as the earliest possible last-alive date. Sensitivity analyses used October 31, 2025, and omitted this patient. Recurrence annotations with month or year precision were displayed as date intervals without assigning an exact recurrence day. Because recurrence sites and surveillance were incompletely characterized, recurrence-free survival and local recurrence incidence were not estimated. Counts of patients with recurrence annotations were reported descriptively.

Analyses used Python 3.12 with NumPy and SciPy. Survival estimates and confidence intervals were checked against SciPy's censored empirical survival implementation. The artificial intelligence (AI) tool ChatGPT (OpenAI) assisted with literature searches, development of analysis and plotting code and language editing. Analyses used observed study data; no synthetic observations were introduced. Bibliographic details and literature-based claims were checked against the cited publications.

Results

Cohort composition

The 26-patient series comprised nine angiosarcomas, six DFSPs, three phyllodes tumors, three sarcomas NOS, two chondrosarcomas, two leiomyosarcomas and one fibrosarcoma (Fig. 1a). Five of the nine angiosarcomas were explicitly described as radiation-associated. The six records without dated tumor resection comprised one phyllodes tumor, one angiosarcoma, one chondrosarcoma and three DFSPs. One of these six patients had a documented death, which could not contribute to survival estimation without a time origin.

The operative cohort contained eight angiosarcomas, two malignant phyllodes tumors and ten other sarcomas. Final R0 resection was achieved in all 20 patients. Median age at the first recorded tumor resection was 55.0 years (interquartile range 44.3–69.8; range 38.6–88.4). Cohort characteristics and reconstructive methods are summarized in Table 1. Four operative cases were explicitly radiation-associated angiosarcomas; radiation association remained unspecified in the other four angiosarcomas.

Table 1

Characteristics of the operative cohort Values are numbers of patients unless specified otherwise. The complete histologic series contains 26 patients; this table describes the 20 patients with a dated tumor resection.

Characteristic	All (n = 20)	Angiosarcoma (n = 8)	Phyllodes (n = 2)	Other (n = 10)
Patients	20	8	2	10
Final R0 resection*	20	8	2	10
Age at resection, years	55.0	64.7	49.3	47.4
Median (range)	(38.6–88.4)	(40.6–88.4)	(40.3–58.3)	(38.6–74.6)
Explicitly radiation-associated angiosarcoma	4	4	0	0
Initial coverage Rectus abdominis flap	5	4	1	0
Initial coverage Other flap	8	0	0	8
Initial coverage Skin graft	3	3	0	0
Initial coverage Primary closure	1	1	0	0
Initial coverage Not specified	3	0	1	2
Mesh reinforcement	4	0	0	4
Any flap during operative course	14	5	1	8
Any TRAM or VRAM during operative course	6	4	1	1
Other histologies comprise three dermatofibrosarcoma protuberans, three sarcomas not otherwise specified, two leiomyosarcomas, one chondrosarcoma and one fibrosarcoma. Both operative phyllodes cases were explicitly malignant. Radiation association was unspecified in four operative angiosarcomas.				
*Final R0 status was retrospectively confirmed by the treating surgical team. Measured margin clearance was unavailable. Initial coverage includes linked procedures within 30 days of the index resection. Mesh is additional to the soft-tissue method. TRAM, transverse rectus abdominis myocutaneous flap; VRAM, vertical rectus abdominis myocutaneous flap. Recurrence annotations do not provide a standardized local recurrence endpoint.				

Characteristic	All (n = 20)	Angiosarcoma (n = 8)	Phyllodes (n = 2)	Other (n = 10)
Patients with recurrence annotations	6	4	1	1
Documented deaths	6	2	1	3
Recorded procedures	45	18	10	17
Other histologies comprise three dermatofibrosarcoma protuberans, three sarcomas not otherwise specified, two leiomyosarcomas, one chondrosarcoma and one fibrosarcoma. Both operative phyllodes cases were explicitly malignant. Radiation association was unspecified in four operative angiosarcomas.				
*Final R0 status was retrospectively confirmed by the treating surgical team. Measured margin clearance was unavailable. Initial coverage includes linked procedures within 30 days of the index resection. Mesh is additional to the soft-tissue method. TRAM, transverse rectus abdominis myocutaneous flap; VRAM, vertical rectus abdominis myocutaneous flap. Recurrence annotations do not provide a standardized local recurrence endpoint.				

Reconstructive procedures

Flaps provided initial coverage in 13 of 20 patients (65.0%). These comprised four TRAM flaps, one VRAM flap and eight other flaps. The latter included latissimus dorsi, pectoralis, epigastric, fasciocutaneous and advancement flaps. Three patients received initial split-thickness skin grafts and one underwent primary closure. Soft-tissue coverage was unspecified in three records, including one that documented mesh reinforcement. Mesh was recorded in four patients overall (Fig. 1b).

Across the documented operative course, 14 patients had at least one flap procedure. One patient initially treated with a skin graft subsequently received an advancement flap during resection of a documented recurrence. Another initially treated with an epigastric flap later underwent TRAM reconstruction and mesh placement; the indication for that later reconstruction was not recorded. Rectus abdominis flaps were therefore documented in six patients during follow-up.

Among the four operative radiation-associated angiosarcomas, three were treated by mastectomy with negative-pressure wound therapy followed by TRAM coverage 5, 6 or 10 days later. The fourth underwent mastectomy with primary closure. One TRAM recipient later underwent recurrence resection followed by skin grafting. The operative summaries did not establish whether the complete previously irradiated field had been excised in any of these four cases.

Overall survival and duration of observation

Six deaths occurred among the 20 patients with a survival origin. Median follow-up by reverse Kaplan–Meier was 15.0 years; the median observed interval to death or censoring was 9.9 years, with a

maximum of 23.7 years. Twelve patients remained at risk at five years, ten at ten years, six at fifteen years and four at twenty years.

Estimated five-year overall survival was 82.0% (95% confidence interval 53.5–93.9) and ten-year survival was 74.5% (44.9–89.8); median overall survival was not reached in the complete operative cohort (Fig. 2a). Eight of the ten patients with at least ten years of observation had a flap documented for their initial defect coverage.

Table 2
Overall survival and sensitivity analyses

Analysis	n	Deaths	5-year OS % (95% CI)	10-year OS % (95% CI)	At risk 5 / 10 years
Primary analysis	20	6	82.0 (53.5–93.9)	74.5 (44.9–89.8)	12 / 10
Excluding DFSP	17	6	77.9 (45.2–92.4)	68.1 (34.7–87.0)	9 / 7
Latest possible partial date	20	6	82.2 (53.9–94.0)	74.7 (45.1–89.9)	12 / 10
Omitting partial-date case	19	6	82.0 (53.5–93.9)	74.5 (44.9–89.8)	12 / 10
OS, overall survival; CI, confidence interval; DFSP, dermatofibrosarcoma protuberans. Survival is measured from the first recorded definitive tumor resection. Confidence intervals use Greenwood variance and a log–log transformation.					
The primary analysis uses October 1, 2025, as the earliest possible last-alive date for S24, whose latest recurrence annotation was recorded only as October 2025. The upper-bound analysis uses October 31, 2025. Omitting S24 leaves the five- and ten-year estimates unchanged because the primary censoring time precedes the first observed death. These analyses address date precision, not possible informative loss to follow-up.					
Excluding DFSP is a sensitivity analysis of histologic composition. The cohorts are nested and are not independent comparison groups. No hypothesis test was performed. Six additional source records lacked a dated tumor resection and are absent from all four survival analyses, including one with a documented death.					

Excluding the three operative DFSP cases yielded a 17-patient sensitivity cohort with six deaths. Estimated five- and ten-year overall survival were 77.9% (45.2–92.4) and 68.1% (34.7–87.0), respectively (Fig. 2b). Using the latest possible rather than earliest possible last-alive date for the patient with an October 2025 entry changed five- and ten-year estimates to 82.2% and 74.7%. Omitting that patient left both primary landmark estimates unchanged (Table 2).

Recurrence annotations and subsequent operations

Six patients had at least one recurrence annotation. Five had their first recorded recurrence within the first postoperative year. The sixth, a patient with DFSP, had a recurrence recorded only by calendar year, corresponding to an interval 9.3–10.3 years after the first recorded resection. In one malignant phyllodes case, repeated tumor resections involved gluteal, groin, abdominal, neck and breast-region sites. These events could not all be classified as local recurrence. The patient-level display therefore shows recurrence annotations without assuming a uniform anatomic endpoint (Fig. 3).

Two of the four operative radiation-associated angiosarcomas had recurrence annotations. Observation in this subgroup ranged from approximately 0.6 to 3.9 years, and all four were censored without a documented death. The fifth radiation-associated case in the complete case list had a recorded death but no dated tumor resection. The available data consequently do not establish five-year survival for radiation-associated angiosarcoma or permit a reliable comparison with other angiosarcomas.

The operative records contained 45 procedures, with a median of two per patient (range 1–6; Fig. 4). Thirty-one were classified as tumor surgery, including procedures with simultaneous reconstruction; six were separate reconstructive procedures, three were wound interventions, three were elective refinements and one was a biopsy. A later forequarter amputation had no stated indication and was retained as unspecified. Wound interventions were explicitly documented in two patients. One required surgery for breast and abdominal donor-site necrosis followed by additional donor-site closure and skin grafting; another underwent debridement and secondary suture after TRAM coverage. Elective refinements comprised contralateral reduction, flap pedicle thinning and breast scar revision.

Discussion

This breast-specific series of patients with final R0 resection documents frequent flap reconstruction and survival extending beyond two decades after surgery. Fourteen of 20 patients underwent flap coverage during their operative course, and ten had at least ten years of observation. These findings place reconstruction within a substantial period of survivorship. The estimated ten-year overall survival of 74.5% applies to this selected, mixed-histology cohort; it does not establish a survival benefit from reconstruction.

Reconstruction in the context of long-term survivorship

The findings extend the clinical perspective provided by earlier breast sarcoma reconstruction series. Crosby and colleagues reported 24 reconstructions in 23 patients, predominantly using autologous tissue, with a median follow-up of 44 months [3]. Carl and colleagues identified 34 patients, 12 of whom underwent reconstruction; their cohort was predominantly composed of malignant phyllodes tumors and had an average follow-up of 58 months [4]. Toesca and colleagues studied a population dominated by

angiosarcoma after excluding phyllodes tumors, illustrating the substantial differences in case composition between breast sarcoma reports [1].

The extended observation in this series captures secondary flap procedures and elective refinement in addition to initial defect coverage. Patients receiving skin grafts, local flaps or rectus abdominis flaps may live for many years after treatment, during which breast contour, donor-site morbidity and further reconstructive options remain relevant. These priorities should be included in long-term follow-up. The present records describe coverage methods, however, and contain no standardized assessment of wound durability, breast volume, sensation or patient satisfaction.

Procedure counts show the different reasons for further surgery. Of 45 recorded operations, 31 were tumor procedures, six were separate reconstructions and three were elective refinements. The three explicitly recorded wound interventions cannot establish a complication rate because ascertainment was incomplete. Comparisons of reconstructive morbidity would require systematic collection of recipient-site complications, donor-site outcomes and patient-reported measures.

Radiation-associated angiosarcoma and resection of the irradiated field

The contemporary move toward broader irradiated-field excision provides an important clinical context for these findings. In Li and colleagues' retrospective study of 76 patients, radical surgery removed all or nearly all irradiated skin together with mastectomy. Five-year disease-specific survival was 86% after radical versus 46% after more conservative resection, and the corresponding cumulative incidence of local recurrence was 23% versus 76% [7]. These associations are clinically relevant, but the treatment groups also differed in chemotherapy exposure and other characteristics. They do not isolate the effect of reconstruction or establish a randomized comparison of resection strategies.

Thiel and colleagues subsequently described entire-field resection in ten patients, using skin grafts in seven and flaps in three. Eight were alive at a median follow-up of 40 months, with three local relapses [8]. This proportion must not be interpreted as five-year overall survival. The operative concept concerns the irradiated skin and associated soft tissues, with deeper resection determined by involvement. It is distinct from routine mastectomy and from removal of every anatomic structure exposed during radiotherapy. Mella and colleagues' 35-patient reconstructive experience similarly demonstrates the range of coverage methods needed after extensive irradiated-skin excision [9].

Our four operative radiation-associated cases document primary closure and staged TRAM coverage, with subsequent grafting in one recurrent course. The summaries do not establish the extent of irradiated-field excision. Evaluating this strategy would require the original radiotherapy plan or a clearly defined field reconstruction, a mapped resection specimen, margin assessment and localization of subsequent recurrence relative to the field. The choice of flap and use of negative-pressure wound therapy provide no substitute for these anatomic data.

The relevance of radiation-associated breast disease is also apparent in our earlier institutional angiosarcoma cohort. Puszcz and colleagues reported 39 patients, including 25 with secondary angiosarcoma; 24 of these secondary tumors involved previously irradiated breast skin [5]. That study characterized clinical outcomes and explored prognostic factors. The present series adds a breast-specific account of defect coverage and subsequent reconstructive procedures alongside extended survival observation.

Systemic and radiation treatments further complicate historical comparisons. Recent retrospective studies associated neoadjuvant taxanes with improved overall survival [12] and (neo)adjuvant chemotherapy and radiotherapy with improved relapse-free survival; the latter study did not establish an overall-survival benefit [13]. A 2026 multi-institutional analysis found that larger tumor size and metastatic presentation were associated with worse overall survival [14]. These variables were unavailable in our dataset. Apparent differences between an older mixed breast sarcoma cohort and contemporary radiation-associated angiosarcoma series should therefore not be attributed to surgical radicality alone.

Histologic composition and interpretation of survival

Combining phyllodes terminology prevents artificial splitting of a single diagnostic entity, but it does not remove biological heterogeneity. The historical phyllodes label without an explicit grade was retained in the descriptive series and did not enter survival analysis because no resection date was available. Both evaluable phyllodes cases were explicitly malignant. This preserves the distinction between nomenclature harmonization and reassignment of pathologic grade, consistent with the need for careful specialist assessment of these lesions [2].

The sensitivity analysis excluding DFSP reduced estimated ten-year survival from 74.5% to 68.1%. Its purpose was to show how composition affects the pooled estimate, rather than justify selective exclusion of a less aggressive subtype. Similarly, four angiosarcomas lacked an explicit radiation-association label; they cannot be treated as a confirmed primary-angiosarcoma comparator. Describing these categories transparently is preferable to deriving subtype-specific survival curves from very small groups with unequal observation periods.

Our previous nomogram study evaluated 31 patients with primary or secondary angiosarcoma and reported higher concordance for Sarculator than for the MSKCC model; this comparison was limited by different prediction horizons and endpoints [6]. Its focus on angiosarcoma etiology and a defined surgical population reinforces the need to distinguish histologic composition and treatment history when interpreting prognosis. The two earlier institutional reports provide context for the present work; patient overlap cannot be excluded, and they are not treated as independent comparator cohorts [5, 6].

Limitations and clinical implications

The principal limitations are the small sample, historical case selection and incomplete source information. Six of 26 records lacked a survival origin, and the completeness of the institutional series

across the treatment era could not be verified. Referral and availability of detailed records may therefore have selected patients with particular clinical courses. The first recorded resection may also follow treatment elsewhere, limiting comparisons with cohorts measured from initial diagnosis or the first lifetime operation.

Pathologic review, tumor burden, measured margin clearance, resection extent and systemic treatment were not available for adjustment. The findings concern patients with final R0 resection and do not establish outcomes with residual disease. Recurrence documentation combined local and non-local events, and telephone vital-status verification did not establish freedom from disease. Some follow-up was older than the 2026 verification period, and one last-alive date required an explicit partial-date convention. The narrow numerical range in that sensitivity analysis addresses the date ambiguity only; it does not resolve potentially informative censoring or missing outcomes. Late survival estimates are imprecise, as shown by their confidence intervals and decreasing numbers at risk.

For clinical practice, the principal observation is that reconstructive care may extend across many years after breast sarcoma resection. Subsequent operations reflect both tumor-related and reconstructive needs. For radiation-associated angiosarcoma, reporting the anatomic extent of irradiated-field excision separately from defect coverage would make future comparisons of resection strategies substantially more informative.

Conclusions

Flap reconstruction was used in 14 of 20 evaluable patients, and survival extended beyond a decade after several methods of defect coverage. These findings support incorporating long-term survivorship into reconstructive planning after R0 resection of breast sarcoma. Histologic composition and incomplete historical records constrain survival comparisons. The oncologic value of complete irradiated-field excision requires anatomically defined resection data linked to recurrence and survival.

Abbreviations

AI
artificial intelligence
CHS
chondrosarcoma
CI
confidence interval
DFSP
dermatofibrosarcoma protuberans
FS
fibrosarcoma
LMS

leiomyosarcoma
MSKCC
Memorial Sloan Kettering Cancer Center
NOS
not otherwise specified
OS
overall survival
R0
microscopically margin-negative resection
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
STSG
split-thickness skin graft
TRAM
transverse rectus abdominis myocutaneous
VRAM
vertical rectus abdominis myocutaneous.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Ruhr University Bochum, Germany (approval no. 20-7126), under the institutional sarcoma registry protocol. Written informed consent for data collection and analysis was obtained from all participants.

Consent for publication

Not applicable. The manuscript presents de-identified study data and contains no clinical photographs or directly identifying patient information. Patient-level displays use study identifiers and relative follow-up times.

Availability of data and materials

The patient-level dataset is not publicly available because it contains sensitive clinical information from a small institutional cohort. Requests for access to de-identified data and analysis code should be addressed to the corresponding author. Access to patient-level data is subject to institutional approval and applicable ethical and data-protection requirements. Aggregate results are reported in this article; Additional file 1 provides the reporting checklist and methodological details.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AF: investigation, data curation, writing – original draft, and writing – review and editing. PD: investigation, data curation, and writing – review and editing. MD: methodology, formal analysis, validation, and writing – review and editing. PW: investigation, data curation, validation, and writing – review and editing. JZ: writing – review and editing. ML: resources, supervision, and writing – review and editing. MG: methodology, clinical interpretation, and writing – review and editing. CW: conceptualization, methodology, software, formal analysis, visualization, supervision, project administration, writing – original draft, and writing – review and editing.

The authors are accountable for the integrity and accuracy of the work.

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Use of artificial intelligence

AI assistance is described in the Methods. The authors remain responsible for verifying AI-assisted content and for the accuracy, originality and integrity of the manuscript.

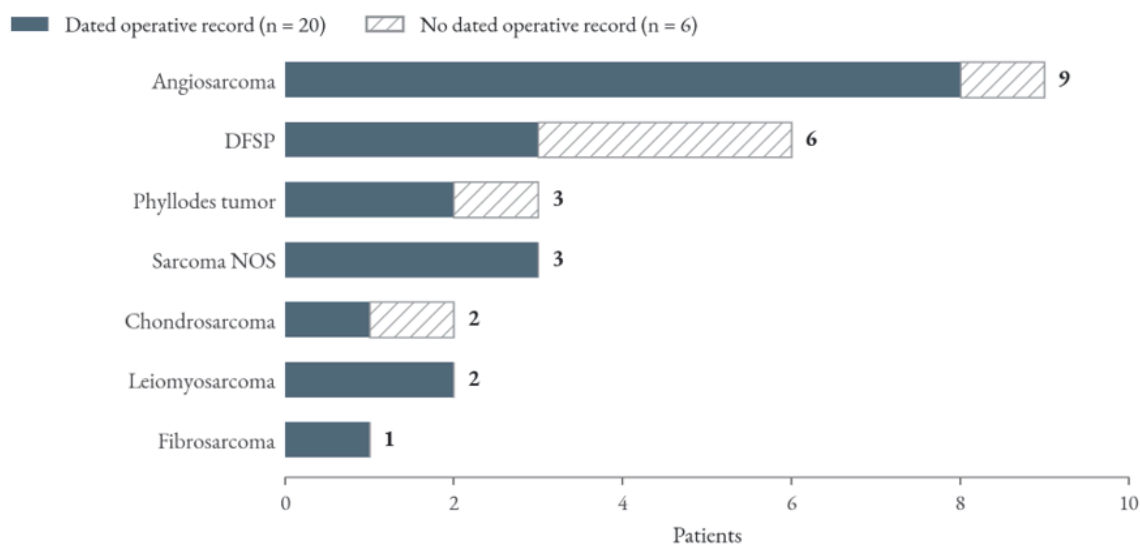
References

1. Toesca A, Spitaleri G, De Pas T, Botteri E, Gentilini O, Bottiglieri L, et al. Sarcoma of the breast: outcome and reconstructive options. Clin Breast Cancer. 2012;12(6):438–44. 10.1016/j.clbc.2012.09.008.
2. Bishr MK, Humphreys A, Ahmed M, Cox K, Hughes A, Isherwood J, et al. Contemporary management of phyllodes tumours of the breast: recommendations from the UK Association of Breast Surgery. Br J Surg. 2025;112(8):znaf152. 10.1093/bjs/znaf152.

3. Crosby MA, Chike-Obi CJ, Baumann DP, Sacks JM, Villa MT, Garvey PB, et al. Reconstructive outcomes in patients with sarcoma of the breast. *Plast Reconstr Surg*. 2010;126(6):1805–14. 10.1097/PRS.0b013e3181f5276f.
4. Carl HM, Calotta NA, Siotos C, Bos TJ, Foster DG III, Manahan MA, et al. Reconstruction options and outcomes for breast sarcoma patients. *Breast J*. 2019;25(4):702–5. 10.1111/tbj.13243.
5. Puszcz F, Ahmadi N, Schmidt SV, Reinkemeier F, Drysch M, Steubing Y, et al. Characteristics, outcomes, and risk factors in primary and secondary angiosarcoma: a retrospective cohort study. *Breast J*. 2025;2025:7158762. 10.1155/tbj/7158762.
6. Steubing Y, Ahmadi N, Puszcz F, Wolff A, Hinzmann J, Reinkemeier F, et al. Risk stratification with Sarcuator and MSKCC in patients with primary and secondary angiosarcoma. *Life (Basel)*. 2024;14(5):569. 10.3390/life14050569.
7. Li GZ, Fairweather M, Wang J, Orgill DP, Bertagnolli MM, Raut CP. Cutaneous radiation-associated breast angiosarcoma: radicality of surgery impacts survival. *Ann Surg*. 2017;265(4):814–20. 10.1097/SLA.0000000000001753.
8. Thiel JT, Bauer M, Daigeler A, Kavaka V, Kolbensschlag J, Steiner D, et al. Radiation-associated angiosarcoma of the breast: radical resection technique of the entire radiation field. *Ther Adv Med Oncol*. 2025;17:17588359251317842. 10.1177/17588359251317842.
9. Mella JR, Ross KM, Li GZ, Pomahac B, Raut CP, Orgill DP. Cutaneous breast radiation-associated angiosarcoma: anterior chest wall reconstruction options following extra-radical resection. *Plast Reconstr Surg Glob Open*. 2018;6(9):e1938. 10.1097/GOX.0000000000001938.
10. Vandembroucke JP, von Elm E, Altman DG, Gøtzsche PC, Mulrow CD, Pocock SJ, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *PLoS Med*. 2007;4(10):e297. 10.1371/journal.pmed.0040297.
11. Schemper M, Smith TL. A note on quantifying follow-up in studies of failure time. *Control Clin Trials*. 1996;17(4):343–6. 10.1016/0197-2456(96)00075-X.
12. van der Burg SJC, Reijers SJM, Kuijpers A, Heimans L, Scholten AN, Haas RLM, et al. Neoadjuvant chemotherapy for radiation associated angiosarcoma (RAAS) of the breast: a retrospective single center study. *Breast*. 2024;78:103825. 10.1016/j.breast.2024.103825.
13. Palassini E, Baldi GG, Ciniselli CM, Gennaro M, Gronchi A, Sangalli C, et al. Outcome improvement with chemotherapy and radiotherapy in primary, localized, radiation-associated angiosarcoma of the breast region: a retrospective case series analysis. *ESMO Open*. 2024;9(6):103474. 10.1016/j.esmoop.2024.103474.
14. Harbrücker M, Hoffmann S, Thiel JT, Jacob-Rehfeld NS, Christ SM, Daigeler A, et al. Clinical and prognostic insights into radiation-associated angiosarcoma: a multi-institutional analysis. *Radiat Oncol*. 2026;21:110. 10.1186/s13014-026-02895-w.

Figures

a Histologic spectrum and operative data availability



b Initial defect coverage in the operative cohort

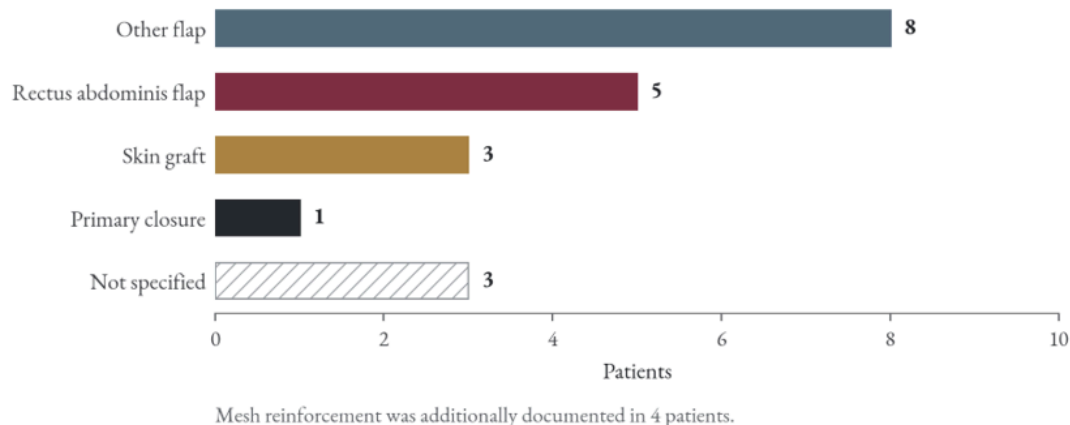
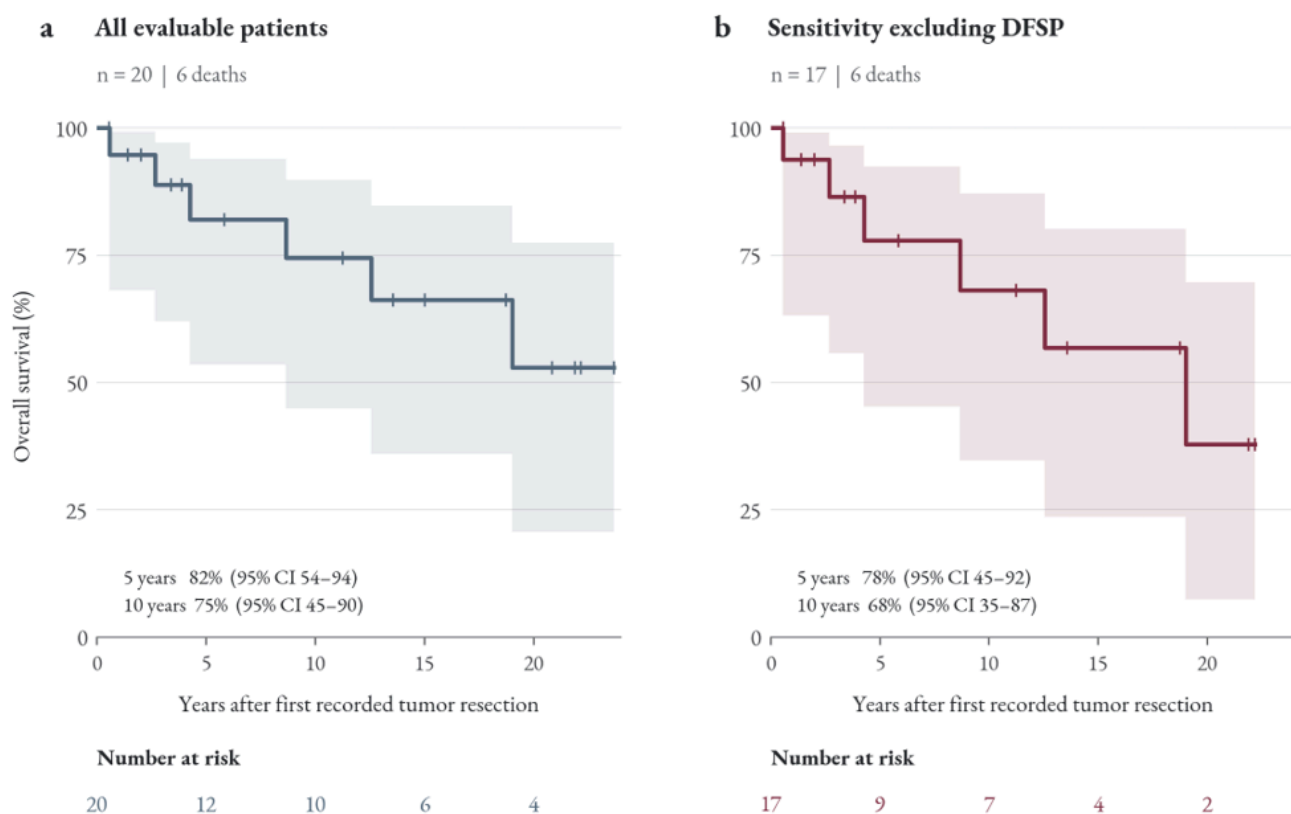


Figure 1

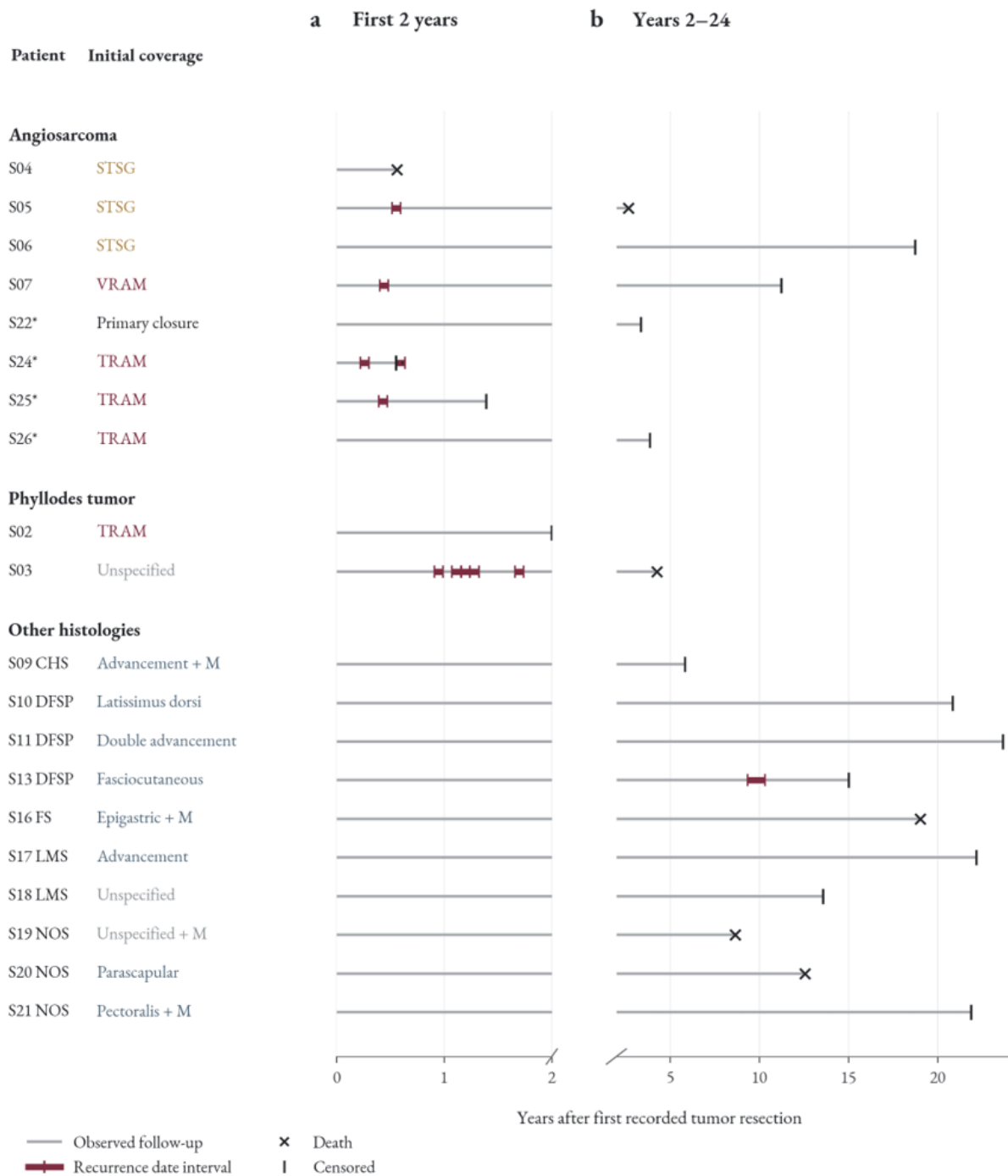
Cohort composition and initial defect coverage. (a) Histology in all 26 records, with the availability of a dated operative record indicated separately. The six records without a dated tumor resection remain part of the descriptive series but do not enter operative or survival analyses. (b) Initial soft-tissue coverage in the 20-patient operative cohort. Rectus abdominis coverage comprises four transverse and one vertical rectus abdominis myocutaneous flap. Other flaps include advancement, latissimus dorsi, pectoralis, epigastric and fasciocutaneous flaps. Categories are mutually exclusive for initial soft-tissue coverage; mesh reinforcement is additional and may coexist with any category. Unspecified coverage is not equivalent to absence of reconstruction. DFSP, dermatofibrosarcoma protuberans; NOS, not otherwise specified.



Shading denotes 95% confidence intervals. Vertical marks indicate censoring.

Figure 2

Overall survival and sensitivity to histologic composition. Kaplan–Meier curves from the first recorded definitive tumor resection in (a) all 20 evaluable patients and (b) the nested 17-patient cohort excluding DFSP. Shading indicates 95% log–log confidence intervals; vertical marks denote censoring. Numbers at risk are shown beneath each curve at the corresponding time points. Curves end at the last observed follow-up and are not extrapolated. The primary analysis uses the earliest possible last-alive date for one month-only entry; alternative date handling is reported in Table 2. Panel b is a sensitivity analysis, not an independent comparator. DFSP, dermatofibrosarcoma protuberans.

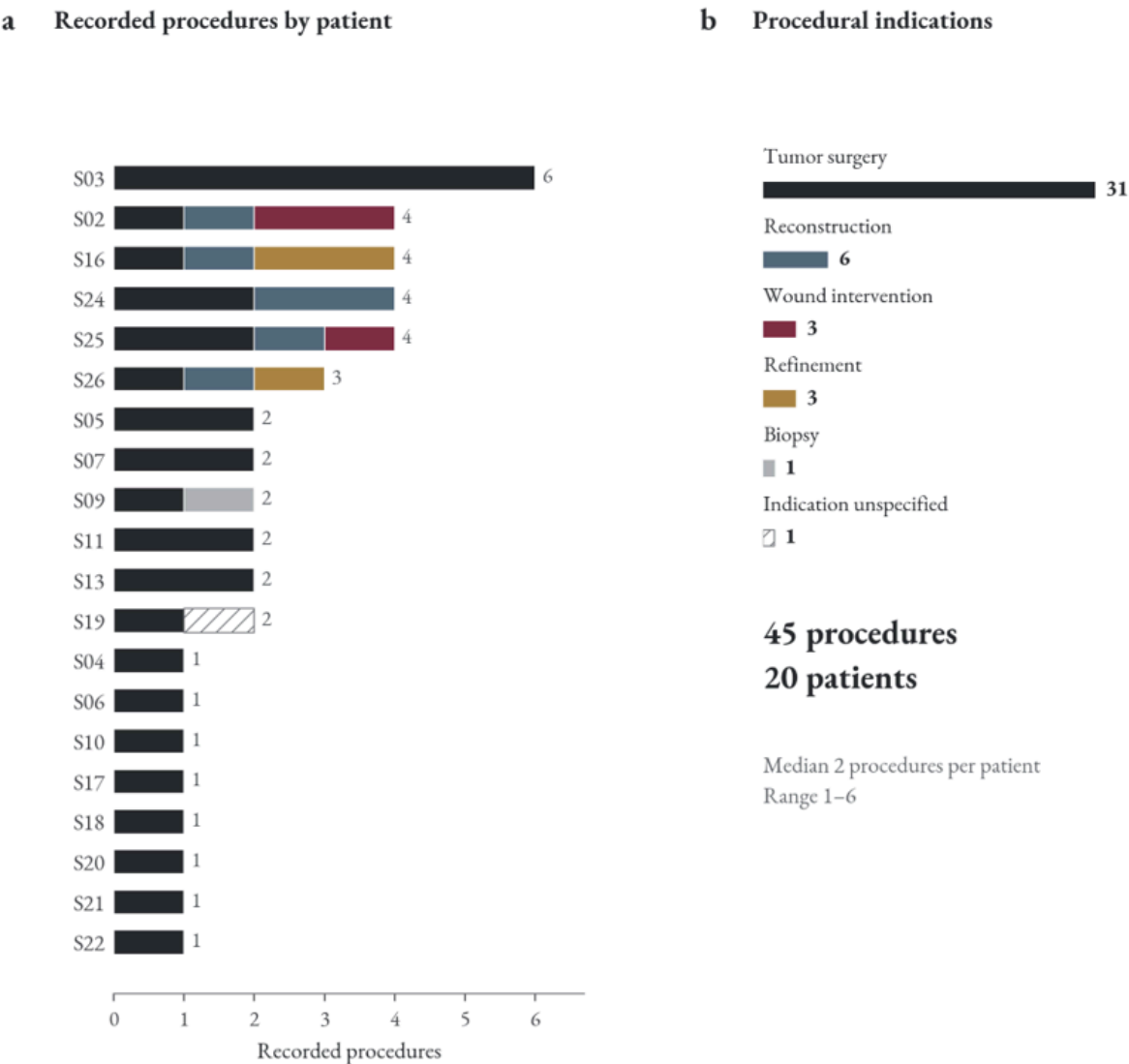


* Radiation-associated angiosarcoma. M = mesh. The two time axes use different scales.

Figure 3

Individual reconstruction and oncologic courses. Each row represents one of the 20 patients with a dated tumor resection. Initial coverage is listed alongside the patient identifier. Panel a expands the first two postoperative years; panel b shows years 2–24 on a different scale. Gray segments indicate observed follow-up and do not imply freedom from disease. Burgundy intervals represent recurrence annotations at the precision available in the source, including a year-only DFSP entry. They include local and incompletely classified non-local events. Crosses indicate death and vertical black marks censoring.

For S24, the censoring mark is the earliest possible last-alive date and the short dotted extension represents the remaining possible date interval. Asterisks identify explicitly radiation-associated angiosarcoma. M, mesh; CHS, chondrosarcoma; DFSP, dermatofibrosarcoma protuberans; FS, fibrosarcoma; LMS, leiomyosarcoma; NOS, sarcoma not otherwise specified; STSG, split-thickness skin graft; TRAM, transverse rectus abdominis myocutaneous flap; VRAM, vertical rectus abdominis myocutaneous flap.



Combined tumor resection and reconstruction are counted once under tumor surgery.
Reconstruction denotes a separate reconstructive procedure; refinement denotes elective revision.
Counts describe the available operative record, not cumulative incidence or complication rates.

Figure 4

Recorded operative burden and procedural classification. (a) All 45 recorded procedures in the 20 operative patients, ordered by total number of procedures. Segments indicate the principal procedural category, not chronological order. (b) Aggregate counts by category. Combined tumor resection and reconstruction is counted once as tumor surgery; its reconstructive component is captured separately in the reconstruction data. Reconstruction denotes a separate coverage procedure, while refinement includes contralateral reduction, pedicle thinning and scar revision. The unspecified operation is a forequarter amputation without a recorded indication. These counts are neither complication rates nor rates of recurrent surgery over a uniform follow-up interval.

Supplementary Files

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