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From an Operable Lesion to an Appropriate Operation: A Multilevel Veterinary Surgical Decision Framework Integrating Anatomy, Biological Behavior, Functional Consequences, Physiological Reserve, and Expected Recovery

Kenji Tanaka[1]*, Yui Kobayashi[1], Takeshi Nakamura[2]

[1]Department of Veterinary Surgery and Perioperative Decision-Making, Faculty of Veterinary Medicine, University of Tokyo, Tokyo, Japan.
[2]Department of Veterinary Surgical Oncology and Functional Recovery, Faculty of Veterinary Medicine, Kyoto University, Kyoto, Japan.

***E-mail** ✉ tanaka.kenji@mail.ecc.u-tokyo.ac.jp

ABSTRACT

Veterinary surgical decisions are often framed around whether a lesion can be removed or a procedure can be technically completed. That framing is insufficient when technical feasibility coexists with uncertain disease control, major functional loss, limited physiological reserve, substantial anesthetic risk, prolonged recovery, or owner and care-environment constraints. This original non-empirical article develops a multilevel surgical-selection framework that separates operability from appropriateness and organizes decision-making across anatomy, lesion biology, local-control expectations, functional consequences, patient reserve, perioperative risk, recovery burden, caregiver feasibility, and alternative treatment pathways. The framework treats these domains as analytically distinct but clinically interacting and emphasizes that some constraints may be noncompensatory: excellence in one domain cannot automatically offset unacceptable burden in another. It also treats surgical selection as revisable rather than fixed, allowing new intraoperative information, conversion, staged procedures, and postoperative outcomes to update the operative plan. The principal contribution is a proposed adjudication architecture rather than a validated score or prediction rule. It is intended to make the reasoning behind operative selection more explicit, auditable, and comparable across cases while preserving uncertainty and owner participation. The supporting evidence is heterogeneous, predominantly canine, and derived from disease-specific cohorts, peri-anesthetic studies, technical investigations, owner research, and measurement studies. Accordingly, the framework requires prospective multispecies and multicenter validation before it can be used as a formal clinical decision instrument.

Keywords: Veterinary surgery, Surgical decision-making, Operability, Physiological reserve, Perioperative risk, Functional outcomes

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Introduction

Technical ability to remove a lesion is only one component of a defensible operative decision. Contemporary veterinary surgical oncology already includes choices among excision strategies, limb-sparing approaches, amputation, prosthetic options, and advanced planning techniques, each with different implications for local control and function [1]. The decision therefore cannot be reduced to a binary question of whether resection is possible.

Owner-facing considerations also enter the decision before the first incision. In dogs presenting with nontraumatic hemoabdomen, treatment choices and perceived outcomes were associated with factors extending beyond the lesion itself, showing that surgery occurs within a patient-owner-clinician decision system [2]. Veterinary clients additionally express a preference for collaborative decisions, clear recommendations, option presentation, and communication of present and future costs [3]. These findings support inclusion of owner feasibility and preference-sensitive deliberation without implying that any single owner factor should determine eligibility.

Patient vulnerability creates a further distinction. In older dogs, a multidomain frailty phenotype was associated with mortality independently of chronological age, indicating that reserve cannot be represented adequately by age alone [4]. This article therefore proposes that surgical appropriateness should be adjudicated across separable domains: technical accessibility, biological behavior, local-control potential, functional cost, physiological reserve, peri-anesthetic risk, recovery burden, and practical feasibility. The framework is explicitly proposed; it is not a validated score, and no domain is assigned a universal weight.

Operability is not equivalent to surgical appropriateness

Operability describes whether an intended procedure can be executed within anatomical and technical limits. Appropriateness asks a broader question: whether performing that procedure is justified for this animal, with this disease, under these perioperative and caregiving conditions, relative to realistic alternatives. A lesion may therefore be operable while the operation remains disproportionate because expected disease control is low, functional loss is excessive, physiological reserve is limited, or recovery demands exceed what can reasonably be sustained.

This distinction also prevents technical innovation from becoming its own indication. Advanced surgical options may expand what can be removed, reconstructed, or approached, but expansion of capability does not itself establish clinical value [1]. Likewise, vulnerability that is not captured by age can materially change how procedural stress is interpreted [4]. The proposed framework therefore treats appropriateness as conditional rather than additive: favorable anatomy does not automatically cancel unfavorable biology, and high expected local control does not automatically neutralize severe functional or perioperative burden.

Appropriateness is also revisable. Owner priorities, emerging diagnostic information, and intraoperative findings can legitimately alter the operative plan. The decision is consequently better viewed as a structured adjudication that can be updated than as a one-time preoperative declaration of "surgical candidate" or "not surgical candidate."

Anatomical accessibility and technical feasibility

Anatomical accessibility concerns whether the operative target can be reached and manipulated with acceptable control of surrounding structures. Technical feasibility concerns whether the planned resection, reconstruction, or stabilization can be performed with available expertise, instrumentation, imaging, positioning, and rescue capability. These are related but not identical: a lesion may be anatomically accessible yet technically demanding because of margin geometry, reconstruction requirements, or proximity to critical structures.

Patient-specific planning can modify this domain. In a canine cadaveric caudal maxillectomy model, a custom three-dimensional printed cutting guide improved the accuracy of several osteotomies for an experienced surgeon compared with freehand execution, while guided procedures required more time [5]. The finding supports a technical-planning benefit under controlled conditions but does not establish improved clinical outcome or appropriateness in live patients.

Clinical use of three-dimensional printed skull models has likewise been described for complex oral and maxillofacial procedures in dogs and cats, including reconstruction planning, ostectomy mapping, and altered neoplastic or traumatic anatomy [6]. Such tools can increase spatial understanding and procedural preparedness, yet they remain adjuncts. The relevant decision question is not simply whether technology makes an operation possible, but whether the newly feasible operation remains biologically useful, functionally acceptable, and proportionate to patient and recovery constraints.

Lesion biology and expected disease behavior

Anatomy defines what can be reached; lesion biology helps determine what local intervention can realistically achieve. In oncologic surgery, the value of resection depends on more than geometric removability. Tumor type, grade, pattern of invasion, metastatic potential, expected local aggressiveness, and responsiveness to other treatment modalities can change the significance of technically complete excision. Contemporary veterinary surgical-oncology practice therefore requires procedure choice to be interpreted within the anticipated behavior of the disease rather than by anatomy alone [1].

This separation is important because identical operations can have different clinical meaning in biologically different lesions. A wide resection may be proportionate when durable local control is plausible, yet the same functional sacrifice may be difficult to justify when systemic progression is likely to dominate outcome. Conversely, modest local surgery may remain appropriate when palliation, symptom control, prevention of ulceration, or restoration of function is the principal goal.

The proposed framework therefore treats lesion biology as an independent evidence domain feeding the appropriateness decision. It should inform the expected benefit of local control, the acceptable magnitude of surgical morbidity, and the interpretation of margins, but it should not be converted into a universal rule. Disease-specific evidence, staging quality, sampling limitations, and temporal change in tumor behavior all constrain confidence.

Surgical margins and local disease control

Margin assessment is central to oncologic surgery, but a binary “clean” versus “incomplete” interpretation can overstate certainty. A critical veterinary oncology review argues that recurrence risk cannot be predicted from microscopic margin status alone because tumor biology, host tissue, and other factors also contribute. In canine cutaneous soft-tissue sarcoma, a dichotomous margin-classification system likewise did not accurately represent local-recurrence risk [7, 8]. These findings support a graded interpretation of margin information rather than a universal binary success criterion.

The practical implication is that margin geometry, lesion biology, histopathologic sampling, and the consequences of additional tissue removal must be considered together. A technically wider margin may improve confidence in local control for some tumors, yet it may also increase functional loss or reconstructive burden. Conversely, a narrow or “close” margin does not have identical meaning across tumor types, anatomical sites, or biological behaviors.

Within the proposed framework, margin status is therefore an evidence input to the local-control domain, not a stand-alone gate for appropriateness. Re-excision, adjuvant treatment, surveillance, or acceptance of residual uncertainty should depend on disease-specific evidence and the cost of further intervention. No universal margin width or deterministic recurrence estimate is implied.

Functional consequences of intervention

Surgical radicality and postoperative function are related, but they are not interchangeable. In a multi-institutional series of dogs and cats undergoing modified hemipelvectomy, substantial resection was generally tolerated in selected patients, although mobility concerns were more evident in animals undergoing more extensive sacral or vertebral involvement [9]. This indicates that the anticipated functional consequence should be estimated from the specific anatomical sacrifice and the individual patient rather than inferred solely from how radical the procedure appears.

Owner-perceived outcome adds another dimension. In a small retrospective series of dogs and cats undergoing double-limb amputation, most owners reported high satisfaction despite the magnitude of anatomical loss, while complications and revision surgery still occurred in some animals [10]. These data are highly selected and cannot define candidacy, but they show why preoperative discussion should distinguish anatomical loss, achievable mobility, assistance requirements, complication burden, and owner-perceived acceptability.

Table 1 crosses the expected long-term functional state with the practical burden of recovery, separating anatomical radicality from the operation’s lived consequences.

Table 1. Operative proportionality at the intersection of long-term function and recovery dependence

Expected long-term functional prospect	Recovery burden is manageable within available care	Recovery requires high or difficult-to-sustain dependence
Function largely preserved	Radical anatomy may remain proportionate when mobility and routine activity are expected to remain acceptable	The operation may still be clinically reasonable, but timing, support, or recovery design must be adapted before commitment
Major adaptation required but an acceptable life is plausible	Discuss assistance, adaptation, complications, and revision explicitly;	Near-term dependence may dominate expected value even when later adaptation is possible

	selected owner reports can inform but not define candidacy	
Welfare-critical irreversible function is likely to be lost	Consider less radical or nonoperative alternatives because local control may not compensate for severe functional harm	The functional boundary and unsustainable recovery burden reinforce a noncompensatory reason to reject or revise the plan

Patient physiological reserve

Physiological reserve describes the capacity to tolerate surgical stress, anesthesia, inflammation, blood loss, immobility, and the metabolic demands of recovery. It is broader than chronological age and should not be reduced to a single comorbidity count. The canine frailty evidence provides a useful conceptual foundation because multidomain vulnerability predicted mortality independently of age in older dogs [4]. However, that evidence does not validate frailty as a surgical eligibility threshold.

Within this framework, reserve is therefore treated as a moderating domain. Two animals with anatomically similar lesions and identical intended procedures may face different operative burdens because baseline strength, endurance, nutritional state, organ function, mobility, and cumulative deficits differ. Reserve should influence how aggressively a clinician interprets expected blood loss, anesthetic duration, postoperative immobility, need for rescue intervention, and capacity for rehabilitation.

The principal boundary is measurement validity. A reserve construct can be clinically useful only if it predicts outcomes relevant to surgery and does so across breeds, ages, diseases, and care settings. Until such validation exists, reserve should structure clinical reasoning rather than function as a binary veto. The proposed framework consequently uses physiological reserve to qualify tolerance of intervention, not to assign a universal point value or age-based exclusion rule.

Anesthetic and perioperative risk

Anesthetic risk is a separate dimension of appropriateness because a technically feasible operation may still impose disproportionate perioperative hazard. In a large UK primary-care population, anesthesia- or sedation-related mortality was uncommon but heterogeneous across patient and procedural characteristics [11]. Population estimates can therefore inform risk awareness without providing precise contemporary risk for an individual referral patient.

Perioperative assessment should also extend beyond survival. In a prospective study of 247 dogs recovering from general anesthesia, poor recovery quality occurred in 29.1% of cases and was associated with selected anesthetic-management variables [12]. Recovery quality therefore represents a clinically relevant burden distinct from mortality, particularly when prolonged dysphoria, delayed mobility, pain-control challenges, or intensive monitoring would materially affect postoperative feasibility.

Laboratory thresholds should likewise be interpreted cautiously. A 2025 data-driven analysis of elective procedures in dogs and cats developed laboratory safety limits under specified false-positive constraints, yet sensitivity for mortality remained limited [13]. Such thresholds may support structured review of abnormal results but should not function as universal stop rules.

The proposed framework therefore treats anesthetic and perioperative risk as a multidimensional estimate combining patient vulnerability, procedure duration and invasiveness, available monitoring and rescue capacity, and anticipated recovery quality. It is neither a substitute for technical assessment nor an automatically compensable risk domain.

Expected recovery burden

Recovery burden begins where operative feasibility ends. A technically successful operation may still impose pain, dysphoria, immobility, dependence, wound care, repeated monitoring, nutritional support, or delayed return to normal behavior. Functional series after major resections show that selected animals can adapt well while still experiencing procedure-specific complications and assistance needs [9]. Owner satisfaction after double-limb amputation can also be high despite major anatomical loss, but such findings come from small, selected cohorts [10]. Prospective anesthesia data further show that recovery quality can vary independently of mortality [12].

The proposed framework therefore separates recovery burden from peri-anesthetic risk and final functional outcome. It asks how intense recovery is likely to be, how long it may persist, what resources are required, and whether deterioration can be recognized and rescued. Short-term burden and long-term adaptation may diverge:

an ultimately acceptable functional state may still require a recovery pathway that is impractical for a particular patient and household. Recovery burden is therefore temporal, conditional, and inseparable from care capacity.

Owner and care-environment constraints

Veterinary surgery is delivered through a care environment, not to an isolated biological patient. In owners of pets evaluated for suspected cancer, caregiver burden was associated with psychosocial distress and challenging treatment routines; broader companion-animal research likewise links caregiver burden with routine disruption and difficulty following management requirements [14, 15]. These findings do not justify excluding an animal because an owner reports strain. They justify asking whether postoperative care can actually be executed.

Feasibility also depends on resources beyond the household. Veterinary professionals and owners have reported cost-related limitations, access barriers, and workforce constraints affecting care delivery [16]. An operation may therefore be medically reasonable yet practically fragile if repeated review, rehabilitation, emergency reassessment, medication administration, transport, or rescue services are unavailable.

Table 2 decomposes care feasibility into the tasks on which postoperative success depends, allowing support or redesign to target the actual weak point.

Table 2. Postoperative care tasks that can make an otherwise reasonable operation practically fragile

Postoperative care task	What the operation may require	How practical fragility becomes visible	Adaptation before operative commitment
Medication and wound care	Repeated administration, observation, and technically reliable wound management	The daily plan cannot be performed consistently	Simplify the regimen, train caregivers, or arrange additional support
Mobility, transfer, and toileting	Lifting, assisted movement, environmental access, or hygiene support	Dependence exceeds household capability or animal tolerance	Modify timing, equipment, assistance, or the operative alternative
Scheduled monitoring and transport	Return visits, rehabilitation, or repeated assessment	Distance, workforce, or transport prevents planned follow-up	Verify local services or choose a monitoring plan that can actually be delivered
Emergency reassessment and rescue	Rapid recognition and access if deterioration occurs	Urgent support is unavailable or delayed	Change timing, location, contingency planning, or procedural burden
Complication and reintervention capacity	Financial and logistical tolerance for foreseeable additional care	The plan becomes unsustainable if complications occur	Compare lower-burden options and make future costs explicit

Comparing operative and nonoperative alternatives

Appropriateness is best judged comparatively. The question is not whether surgery has benefit in isolation, but whether its expected disease control, functional consequences, perioperative burden, recovery demands, caregiver feasibility, and rescue options are preferable to realistic alternatives for this animal. Surgical oncology offers technically plausible strategies with different local-control and functional implications [1]. Major resections may yield acceptable function in selected patients [9], but this must be weighed against complications, adaptation demands, and owner-perceived outcomes [10].

Nonoperative management, palliation, surveillance, multimodal therapy, delayed intervention, or euthanasia may remain legitimate comparators depending on disease biology and goals. Owner burden [14] and access constraints [16] can affect every option, not merely surgery. Collaborative option presentation is particularly important when no approach dominates [3].

The proposed comparison rule is nonnumeric. Favorable findings in several domains should not mathematically cancel a severe noncompensatory problem elsewhere. Clinicians should identify unacceptable constraints first, then compare remaining options across benefit, burden, reversibility, uncertainty, and owner priorities.

A proposed multilevel surgical-selection framework

The framework organizes surgical selection as conditional adjudication across interacting levels rather than as a summed score. Multivariable evidence from canine adrenalectomy illustrates why: outcome-relevant information can arise simultaneously from dog-, tumor-, treatment-, and surgery-related variables [17]. Those procedure-specific coefficients cannot be transferred elsewhere, but the structure supports resisting single-domain selection.

Patient reserve forms a separate level. A canine Frailty Index based on accumulated deficits was strongly related to mortality and captured vulnerability not reducible to age [18]. Yet even a plausible construct requires validation before becoming a decision rule; work proposing canine frailty instruments explicitly distinguishes development from validation [19].

Five adjudication questions follow: Is meaningful disease control plausible? Is the operation technically achievable without unacceptable compromise? Is resulting function compatible with welfare-critical behavior? Can reserve and perioperative support absorb the stress? Is recovery executable within the owner and care environment? A severe constraint may be noncompensatory. If no such boundary is crossed, acceptable options are compared rather than scored. The decision remains provisional: material new information should trigger reassessment of the same domains.

This architecture also separates uncertainty from contraindication. Uncertain evidence may justify additional diagnostics or preference-sensitive choice, whereas a clearly unacceptable functional or rescue boundary may prevent escalation. That distinction should remain visible rather than being obscured by an aggregate risk label.

Because parallel evidence, noncompensatory boundaries, and reassessment cannot be represented adequately as a linear checklist, the decision logic is summarized visually below **(Figure 1)**.

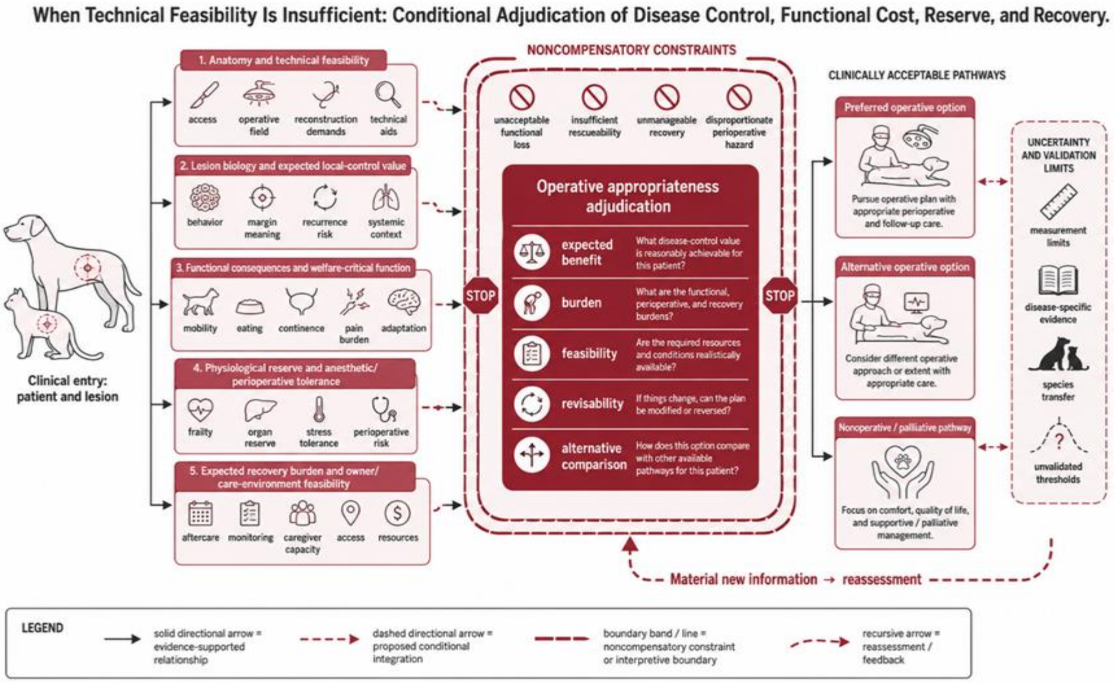

Figure 1. When Technical Feasibility Is Insufficient: Conditional Adjudication of Disease Control, Functional Cost, Reserve, and Recovery

Intraoperative findings and revision of the operative plan

Preoperative planning cannot eliminate intraoperative uncertainty. New anatomy, tissue behavior, bleeding, unexpected invasion, inability to achieve the planned margin, or failure of guidance technology may change the balance between intended benefit and procedural cost. Fluorescence-guided surgery illustrates the measurement problem: system performance can vary with operating-room lighting and imaging platform, so a visual signal should not be treated as ground truth without understanding its conditions [20].

Standardization improves interpretability. A semi-quantitative workflow for indocyanine-green fluorescence in companion-animal lymph-node specimens showed strong agreement between visual scoring and image analysis under defined conditions while identifying factors that can degrade interpretation [21]. Clinical experience likewise shows why revision must remain possible: during near-infrared fluorescence-guided minimally invasive iliosacral lymph-node removal, two of 18 dogs required conversion to open surgery because of specific intraoperative limitations [22].

The proposed rule is evidence-bounded: intraoperative information should change the plan only when clinically material, sufficiently credible, and capable of altering expected control, function, safety, or recovery. Revision should also be documented as a change in the decision state, not merely as a technical event. The record should identify what changed, how confidence was established, and which appropriateness domain was materially altered.

Table 3 distinguishes direct operative evidence from technology-dependent signals and loss of procedural control, linking each source to the scope of plan change it can legitimately support.

Table 3. Intraoperative information ranked by how it can support refinement, verification, conversion, or abandonment

Source of new intraoperative information	Credibility check before changing course	Reversible adjustment	When conversion, staging, or abandonment becomes proportionate
Materially different anatomy or tissue behavior	Confirm the finding directly and reconsider critical structures, margin geometry, and reconstruction	Alter exposure, sampling, or the planned extent while preserving options	When the revised technical or functional cost no longer supports the original objective
Reproducible fluorescence or navigation signal	Verify device, lighting, tracer, and anatomical correspondence under validated conditions	Refine localization or targeted excision as one operative input	Only when independent operative evidence also shows that the original route is unreliable
Weak, absent, or discordant guidance signal	Correct ambient light, perfusion, fat, tracer, or device conditions and seek alternative confirmation	Pause irreversible escalation and repeat or substitute the measurement	When reliable control cannot be restored and continuing would create disproportionate risk
Loss of reliable minimally invasive control	Establish whether localization, capsular integrity, or safe manipulation can be recovered	Stage or alter the minimally invasive component if control can be regained	Convert or abandon the component when reliable completion is no longer achievable

Rescue, conversion, and staged procedures

A rescue pathway belongs in planning when foreseeable deterioration or technical failure could require greater exposure, transfusion, intensive monitoring, or postoperative escalation. Conversion should therefore be distinguished from failed judgment. In the fluorescence-guided iliosacral-node series, open conversion was used when the minimally invasive strategy no longer provided reliable conditions [22]. The question is whether the revised operation remains proportionate after its new functional and recovery burdens are considered.

The same logic applies to revision and staging. Major resections can produce acceptable outcomes in selected animals while complication and adaptation patterns remain procedure specific [9]. Revision after major limb loss also occurred in a minority of double-amputation cases [10]. These observations support contingency planning but not universal rescue thresholds.

The proposed framework requires foreseeable alternatives to be considered before irreversible commitment. If new circumstances materially increase morbidity, the revised plan should be re-adjudicated across disease-control value, anatomy, function, reserve, perioperative support, and recovery feasibility. Abandonment, conversion, or staging may therefore be appropriate adaptation when continuing the original plan becomes disproportionate.

Postoperative functional outcomes

Operative appropriateness can be judged retrospectively only if outcomes are measured beyond technical completion. Owner-reported function is useful but requires instruments with known measurement properties. A COSMIN evaluation of canine orthopedic outcome measures found sufficient content validity for several instruments while identifying gaps, including limited evidence on measurement error [23]. Postoperative function should therefore not be reduced to informal impression when validated, context-appropriate measures exist.

Context may also modify apparent outcome. An observational cohort of 460 dogs undergoing thoracolumbar hemilaminectomy specifically examined whether weekday versus weekend timing was associated with postoperative outcome [24]. Such designs demonstrate that service conditions can be tested rather than assumed irrelevant.

Outcome horizons should also extend beyond early recovery. Comparative canine neurosurgical evidence evaluates both postoperative outcome and recurrence after alternative procedures for thoracolumbar arachnoid diverticula [25]. The framework therefore distinguishes early recovery, functional adaptation, recurrence, reintervention, and owner-perceived quality of life. Improvement in one does not guarantee improvement in another. Validation should determine which outcome set best captures whether an operation was appropriate rather than merely feasible.

Implementation in surgical decision-making

The framework is intended as a structure for deliberation, not a bedside score. Implementation would begin by defining the clinical objective, listing realistic operative and nonoperative alternatives, and documenting evidence in each domain. Shared decision-making should make uncertainty and future costs visible rather than present technical feasibility as a single recommendation [3]. Clinicians would identify noncompensatory constraints, compare remaining options, and document contingency plans.

Implementation also requires separating modifiable from nonmodifiable constraints. Caregiver workload may sometimes be reduced through simpler aftercare or support [14], while access limitations may require altered timing or follow-up [16]. Intraoperative technologies should be incorporated with known operating limitations [20], and plan changes should depend on credible evidence rather than technological availability alone [21].

A practical record could preserve the objective of surgery, unresolved uncertainties, reasons an option was rejected, owner-dependent assumptions, and predefined triggers for conversion or reassessment. This would enable later review without implying that documentation validates the framework.

The selected literature does not establish that this process improves survival, welfare, owner satisfaction, or resource use. Its proposed value is transparency. Implementation studies should therefore assess clinical outcomes alongside inter-clinician agreement, documentation quality, owner understanding, decision conflict, plan changes, and unintended consequences.

Validation priorities

Validation should begin with the framework's constructs rather than predictive performance. Veterinary measurement research illustrates the need for staged content development, construct testing, reliability assessment, and responsiveness before an instrument is treated as clinically interpretable [26]. Framework domains therefore require operational definitions and testing for overlap, missing constructs, and inter-rater agreement.

Prospective evaluation should follow. A canine frailty phenotype was developed in one phase and then prospectively assessed in 198 older dogs across different hospital services, illustrating movement from construct development toward broader clinical testing [27]. A surgical-selection framework would need analogous multicenter evaluation across procedures, species, diseases, and practice environments, with prespecified subgroup analyses and external calibration if prediction is attempted.

Interpretability is equally important. Canine health-related quality-of-life research has developed norm-based outputs and minimum important differences to distinguish measurable from meaningful change [28]. Surgical validation should similarly predefine meaningful outcomes across complications, function, recovery burden, recurrence, owner outcomes, and resource use.

Validation must examine decision impact, not prediction alone. A framework could discriminate risk yet worsen care through excessive deferral, unnecessary radicality, inequitable exclusion, or false reassurance. Comparative implementation studies should therefore measure intended benefits and decision-related harms. Only after construct validity, reproducibility, prospective association, calibration, and decision-impact testing should simplified rules or thresholds be considered.

Conclusion

An operable lesion does not necessarily justify an operation. Appropriate veterinary surgical selection requires consideration of what can technically be done, what local intervention is likely to achieve, what function may be lost or preserved, how much physiological and perioperative stress the patient can tolerate, and whether recovery can be executed safely within the owner and care environment. The framework proposed here keeps these domains separate, recognizes noncompensatory constraints, compares realistic alternatives without unsupported numerical weighting, and permits reassessment when new information changes the balance. Its purpose is to make surgical reasoning explicit rather than replace judgment with a score. The evidence remains heterogeneous and predominantly canine, and it does not establish prospective performance or universal applicability. Multicenter validation, reproducible measurement, outcome interpretability, and decision-impact testing are therefore required before formal clinical use.

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