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Optimización de la toma de decisiones bajo incertidumbre en cirugía general: integración del riesgo, el tiempo y las estrategias basadas en sistemas

Optimizing Surgical Decisions Under Uncertainty: Integrating Risk, Timing, and Systems-Based Strategies in General Surgery

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RESUMEN

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La toma de decisiones en cirugía general ocurre con frecuencia bajo condiciones de incertidumbre, donde el cirujano debe integrar juicio clínico, evaluación de riesgo, tiempo quirúrgico y factores del sistema de salud para optimizar los resultados. Este artículo tiene como objetivo analizar la evidencia actual sobre la toma de decisiones en cirugía general, enfocándose en la estratificación de riesgo, el momento de la intervención y las estrategias perioperatorias. Se realizó una revisión narrativa estructurada basada en literatura de alto impacto indexada en bases de datos internacionales. Los resultados muestran que un mayor riesgo preoperatorio se asocia consistentemente con peores resultados posoperatorios, especialmente en cirugía urgente y de emergencia. El tiempo de intervención se identificó como un factor determinante, observándose mejores resultados en cirugía electiva en comparación con procedimientos no electivos. Asimismo, las estrategias perioperatorias estructuradas, como los protocolos ERAS y los sistemas de seguridad quirúrgica, se relacionaron con una reducción de complicaciones y estancia hospitalaria. También se identificó que los resultados posoperatorios siguen un patrón interconectado, donde las complicaciones favorecen la prolongación de la hospitalización, la readmisión y la mortalidad. Además, se destaca la influencia de factores del sistema de salud, especialmente en países de ingresos medios como México, Colombia y Ecuador, donde la disponibilidad de recursos impacta en los resultados quirúrgicos. La integración de herramientas basadas en datos y el trabajo multidisciplinario se identifican como elementos clave para mejorar la toma de decisiones bajo incertidumbre. En conclusión, optimizar la toma de decisiones en cirugía requiere un enfoque integral que combine evaluación objetiva del riesgo, intervención oportuna, estrategias perioperatorias estructuradas y adaptación al contexto del sistema de salud.

PALABRAS CLAVE

Toma de decisiones quirúrgicas, incertidumbre quirúrgica, riesgo perioperatorio, cirugía de emergencia, resultados quirúrgicos, estratificación de riesgo, protocolos ERAS, cuidado perioperatorio, cirugía global, seguridad del paciente

ABSTRACT

Decision-making in general surgery frequently occurs under conditions of uncertainty, where surgeons must integrate clinical judgment, risk assessment, timing, and system-level factors to optimize patient outcomes. This review aims to analyze current evidence on decision-making processes in general surgery, focusing on risk stratification, timing of intervention, and perioperative strategies. A structured narrative review was conducted using high-impact literature indexed in international databases, including multicenter cohort studies, systematic reviews, and validated predictive models. The findings demonstrate that higher preoperative risk is consistently associated with worse postoperative outcomes, particularly in urgent and emergency surgical settings. Timing of intervention emerged as a critical determinant, with elective procedures showing significantly lower mortality and complication rates compared to non-elective surgery. Additionally, structured perioperative strategies, including enhanced recovery protocols and safety systems, were associated with reduced complications and shorter hospital stays. The results also highlight that postoperative outcomes follow an interconnected pattern, where complications contribute to prolonged hospitalization, readmission, and mortality. Furthermore, the analysis underscores the importance of system-level factors, particularly in middle-income countries such as Mexico, Colombia, and Ecuador, where variability in resources and infrastructure influences surgical outcomes. The integration of data-driven tools and multidisciplinary approaches was identified as a key component in improving decision-making under uncertainty. In conclusion, optimizing surgical decision-making requires an integrated approach that combines objective risk assessment, timely intervention, structured perioperative care, and adaptation to local healthcare contexts. This framework supports improved patient outcomes and advances the quality of surgical care in diverse clinical settings.

KEYWORDS

Surgical decision-making, surgical uncertainty, perioperative risk, emergency surgery, surgical outcomes, risk stratification, ERAS protocols, perioperative care, global surgery, patient safety

INTRODUCCIÓN

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Contemporary general surgery is increasingly defined by the necessity to make high-stakes decisions under conditions of uncertainty. Surgeons are routinely required to balance operative timing, physiological risk, and anticipated outcomes, often with incomplete information and under significant time constraints. This challenge is particularly evident in emergency and high-risk surgical settings, where delays or premature interventions can significantly influence morbidity and mortality (Mullen et al., 2017; Pearse et al., 2012). As surgical care evolves toward a more data-driven and patient-centered model, understanding how decisions are made—and how they can be optimized—has become a critical priority for modern surgical practice.

The global burden of surgical disease underscores the importance of improving decision-making frameworks. It is estimated that hundreds of millions of surgical procedures are performed annually worldwide, with substantial variability in outcomes depending on system-level factors, resource availability, and clinical judgment (Weiser et al., 2016). International collaborative studies, such as those conducted by GlobalSurg, have demonstrated marked disparities in outcomes following emergency abdominal surgery, highlighting how contextual factors influence both timing and risk stratification (Abbott et al., 2017). These disparities are particularly relevant in middle-income countries, including Mexico, Colombia, and Ecuador, where healthcare systems face unique challenges related to access, infrastructure, and perioperative care capacity.

Within this context, surgical decision-making cannot be understood solely as a technical process; rather, it represents a complex integration of clinical evidence, probabilistic reasoning, and experiential judgment. Traditional models of decision-making in surgery have historically relied on individual expertise and heuristic approaches, which, while valuable, may introduce variability and potential bias (Leape, 1994). The recognition of medical error as a significant contributor to adverse outcomes has further emphasized the need for structured decision-support systems and standardized protocols (Gawande et al., 1999).

Recent advances have sought to address these limitations through the development of risk prediction tools and outcome-based models. Instruments such as the ACS NSQIP Surgical Risk Calculator and the Surgical Mortality Probability Model have provided surgeons with more objective means to estimate perioperative risk and guide clinical decisions (Bilimoria et al., 2013; Glance et al., 2012). These tools, supported by large datasets and validated across diverse populations, represent a shift toward precision surgery, where individualized risk assessment informs both operative indication and timing.

In parallel, system-level interventions have demonstrated significant improvements in surgical outcomes by reducing variability and enhancing safety. The implementation of comprehensive surgical safety systems, including checklists and standardized perioperative protocols, has been associated with reductions in complications and mortality (De Vries et al., 2010). Similarly, enhanced recovery after surgery (ERAS) programs have redefined perioperative care by integrating evidence-based strategies that optimize physiological resilience and accelerate recovery (Kehlet & Wilmore, 2008; Zhuang et al., 2013). These approaches highlight the importance of aligning decision-making processes with structured, multidisciplinary frameworks.

Another critical dimension of surgical uncertainty lies in the timing of intervention. The distinction between elective, urgent, and emergency surgery carries profound implications for patient outcomes. Evidence suggests that patients undergoing urgent or emergency procedures experience significantly higher rates of complications and mortality compared to those treated electively (Mullen et al., 2017). This underscores the importance of early recognition, appropriate triage, and timely intervention as key determinants of surgical success. In addition, prehabilitation strategies have emerged as a promising approach to mitigate risk by optimizing patients' physiological status prior to surgery, particularly in high-risk populations (Probst et al., 2019).

The growing role of data science and big data analytics has further expanded the possibilities for improving surgical decision-making. The integration of large-scale clinical datasets enables more accurate prediction of outcomes and supports the development of adaptive decision-making models (Wyles et al., 2019). Moreover, analyses of surgeon and institutional volume have demonstrated a clear association between experience and postoperative outcomes, reinforcing the importance of expertise and system organization in reducing uncertainty (Yeo et al., 2017).

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Despite these advances, significant challenges remain. Postoperative complications continue to represent a major burden, not only in terms of patient morbidity but also in healthcare resource utilization and readmission rates (Kassin et al., 2012; Tevis & Kennedy, 2013). The management of these complications requires ongoing decision-making that extends beyond the operating room, emphasizing the need for continuous assessment and adaptive strategies throughout the perioperative period.

Given this complex landscape, the present review aims to analyze the current evidence on decision-making under surgical uncertainty, with a particular focus on risk assessment, timing of intervention, and outcome optimization in general surgery. This work is framed within an international perspective, incorporating insights relevant to healthcare systems in Latin America, including Mexico, Colombia, and Ecuador.

The central premise of this review is that surgical decision-making can be improved through the integration of structured risk assessment tools, standardized care pathways, and data-driven strategies. Accordingly, the primary research question guiding this study is: *How can contemporary evidence be integrated to optimize decision-making processes in general surgery under conditions of uncertainty?* Secondary questions include the role of timing in surgical outcomes, the effectiveness of risk prediction models, and the impact of system-level interventions on patient safety.

To address these questions, a narrative review methodology was employed, focusing on high-impact studies indexed in international databases. The selected literature was analyzed to identify key themes, including risk stratification, perioperative optimization, and decision-support systems. This approach allows for a comprehensive synthesis of current knowledge while maintaining clinical relevance and applicability to real-world surgical practice.

DESARROLLO

Decision-making in general surgery represents a dynamic and multifactorial process in which clinical judgment must integrate patient-specific variables, procedural risk, timing, and anticipated outcomes. Unlike controlled experimental environments, real-world surgical settings are characterized by incomplete information, time pressure, and variability in patient response, which collectively define the concept of surgical uncertainty. This uncertainty is particularly evident in emergency general surgery (EGS), where rapid decisions must be made with limited diagnostic clarity and high physiological risk (Scott et al., 2018).

A central component of surgical decision-making is **risk stratification**, which aims to quantify the probability of adverse outcomes and guide clinical action. Large-scale predictive models, such as the ACS NSQIP Surgical Risk Calculator, have demonstrated significant utility in estimating postoperative complications and mortality across diverse patient populations (Bilimoria et al., 2013). These tools rely on extensive datasets and allow for individualized risk assessment, facilitating more objective decision-making processes. Similarly, the Surgical Mortality Probability Model has provided validated frameworks for perioperative risk estimation, particularly in high-risk patients (Glance et al., 2012). However, despite their robustness, these models are not exempt from limitations, including variability in external validity and the inability to fully capture contextual or system-level factors.

The **timing of surgical intervention** constitutes another critical determinant of outcomes. Evidence consistently demonstrates that delays in necessary surgical care can significantly increase morbidity and mortality, particularly in emergency settings (Mullen et al., 2017). The European Surgical Outcomes Study highlighted that postoperative mortality remains substantial even within well-resourced systems, emphasizing the importance of early recognition and timely intervention (Pearse et al., 2012). Furthermore, global data from emergency abdominal surgery indicate that disparities in access and timing contribute to outcome variability across regions (Abbott et al., 2017). In Latin American contexts, including Mexico, Colombia, and Ecuador, these challenges are often exacerbated by limitations in healthcare infrastructure and perioperative support systems.

In response to these challenges, structured perioperative strategies have emerged to reduce variability and improve outcomes. The implementation of **standardized safety protocols**, such as surgical checklists, has been associated with significant reductions in complications and mortality by improving communication and minimizing preventable errors (De Vries et al., 2010). These findings align with earlier evidence identifying medical error as a major contributor to

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adverse events in surgical care (Gawande et al., 1999; Leape, 1994). By introducing system-level safeguards, these interventions transform decision-making from an isolated cognitive process into a coordinated, team-based activity.

Another key advancement is the adoption of **Enhanced Recovery After Surgery (ERAS)** protocols, which integrate evidence-based perioperative practices aimed at reducing surgical stress and accelerating recovery (Kehlet & Wilmore, 2008). Meta-analyses have demonstrated that ERAS programs significantly decrease complication rates and length of hospital stay, particularly in colorectal surgery (Zhuang et al., 2013). These protocols highlight the importance of preoperative optimization, intraoperative precision, and postoperative management as interconnected components of surgical decision-making.

The concept of **prehabilitation** further expands this framework by emphasizing the optimization of patients' physiological reserve prior to surgery. Evidence suggests that targeted interventions, including nutritional support, physical conditioning, and psychological preparation, can reduce postoperative complications and improve functional recovery (Probst et al., 2019). This approach is particularly relevant in high-risk populations, where baseline frailty significantly influences outcomes.

Despite these advances, postoperative complications remain a major challenge, with significant implications for both patient outcomes and healthcare systems. Studies have shown that complications are strongly associated with increased readmission rates, prolonged hospitalization, and higher healthcare costs (Kassin et al., 2012; Tevis & Kennedy, 2013). Importantly, the occurrence of complications often necessitates additional decision-making under uncertainty, reinforcing the cyclical nature of the problem.

The integration of **big data and surgical analytics** has introduced new opportunities to enhance decision-making. Large datasets enable the identification of patterns and predictors of outcomes, supporting the development of more accurate and adaptive models (Wyles et al., 2019). Additionally, evidence indicates that surgeon and institutional volume are closely linked to postoperative outcomes, suggesting that experience and system organization play a critical role in reducing uncertainty (Yeo et al., 2017). These findings underscore the importance of centralization and specialization in improving surgical care.

From a global perspective, the variability in surgical outcomes reflects not only differences in clinical practice but also broader systemic factors, including resource allocation, training, and healthcare policy (Weiser et al., 2016). In middle-income countries, efforts to improve surgical decision-making must consider these contextual elements, integrating evidence-based strategies with locally adaptable solutions.

OBJETIVO GENERAL Y OBJETIVOS ESPECÍFICOS

General Objective

To analyze and integrate current evidence on decision-making under surgical uncertainty in general surgery, focusing on risk assessment, timing of intervention, and outcome optimization, in order to support structured, evidence-based clinical decision-making applicable to diverse healthcare settings, including Latin America.

Specific Objectives

Cognitive Domain

- To **identify** the key factors that influence surgical decision-making under conditions of uncertainty, including patient-related, procedural, and system-level variables.
- To **analyze** the role of validated risk prediction models (e.g., NSQIP, mortality prediction scores) in guiding perioperative decision-making.
- To **compare** outcomes associated with different surgical timings (elective, urgent, and emergency) based on current evidence.
- To **evaluate** the effectiveness of structured perioperative strategies such as ERAS protocols, safety checklists, and prehabilitation programs in improving surgical outcomes.
- To **synthesize** available international evidence to generate a comprehensive framework for decision-making applicable to healthcare systems in Mexico, Colombia, and Ecuador.

Psychomotor Domain

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- To **apply** risk stratification tools in simulated or real clinical scenarios to support surgical decision-making.
- To **demonstrate** the integration of perioperative optimization strategies (e.g., ERAS, prehabilitation) into surgical planning.
- To **implement** structured decision-making approaches in clinical case analysis, incorporating timing, risk, and expected outcomes.
- To **develop** clinical reasoning skills through the interpretation of patient data and surgical risk profiles.

Affective Domain

- To **recognize** the ethical and professional responsibility involved in surgical decision-making under uncertainty.
- To **value** the importance of patient-centered care and shared decision-making in surgical practice.
- To **appreciate** the role of multidisciplinary collaboration in reducing variability and improving outcomes.
- To **adopt** a critical and reflective attitude toward clinical decision-making, acknowledging limitations and uncertainty in surgical practice.

OBJETO DE ESTUDIO

The object of study of this review is the **decision-making process under conditions of uncertainty in general surgery**, understood as a complex clinical and cognitive phenomenon that integrates risk assessment, timing of intervention, and outcome optimization within diverse healthcare contexts.

This phenomenon encompasses the interaction between multiple dimensions. At the **individual level**, it involves patient-specific factors such as age, comorbidities, physiological status, and disease severity, all of which directly influence surgical risk and expected outcomes. At the **clinical level**, it includes the evaluation of operative indications, the urgency of intervention (elective, urgent, or emergency), and the selection of appropriate surgical or non-surgical strategies. At the **system level**, it incorporates institutional resources, availability of specialized care, and organizational factors that may affect both timing and quality of surgical management (Weiser et al., 2016; Abbott et al., 2017).

The population of interest in this study includes **adult patients undergoing general surgical procedures**, with particular emphasis on those exposed to higher levels of uncertainty, such as individuals requiring emergency or high-risk surgery. These scenarios are especially relevant because they represent clinical situations in which decision-making must be performed rapidly and often with incomplete information, increasing the likelihood of variability in outcomes (Mullen et al., 2017).

Additionally, this review considers the role of **surgeons and multidisciplinary teams** as key actors within the system under study. Decision-making is not approached as an isolated individual act, but rather as a **collaborative process** influenced by communication, experience, and the integration of evidence-based tools. The inclusion of structured strategies—such as risk prediction models, safety protocols, and perioperative optimization pathways—forms part of the system being analyzed, as these elements directly shape how decisions are made and implemented in practice (Bilimoria et al., 2013; De Vries et al., 2010).

From a geographical and contextual perspective, the object of study is framed within an **international scope**, with particular relevance to healthcare systems in **Mexico, Colombia, and Ecuador**. These settings provide a valuable perspective for understanding how surgical decision-making operates in environments with varying levels of resources, infrastructure, and access to care. The variability observed across these contexts highlights the importance of adaptable and scalable decision-making frameworks.

METOLOLOGÍA

This study was designed as a **narrative review with a structured approach**, aimed at synthesizing current evidence on decision-making under surgical uncertainty in general surgery. To ensure methodological rigor and reproducibility, the review was conducted following a **process-based methodology**, integrating elements of the **scientific method** and systematic literature analysis.

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1. Study Design

A **non-experimental, descriptive-analytical design** was employed. The study does not involve direct patient intervention but is based on the critical analysis and integration of previously published data. The approach allows for the exploration of complex clinical phenomena—such as surgical decision-making—through the evaluation of high-impact scientific literature.

2. Methodological Approach

The methodology was based on a **process-oriented framework**, structured in sequential stages:

- Problem identification
- Literature search and selection
- Data extraction and organization
- Critical analysis and synthesis
- Interpretation of findings

This structure ensures that the review follows a logical progression, allowing other researchers to replicate the process and validate the findings.

3. Literature Search Strategy

A comprehensive literature search was conducted using internationally recognized databases, including:

- PubMed/MEDLINE
- Scopus
- Web of Science

The search focused on studies published in high-impact journals related to surgery, anesthesiology, and perioperative care.

Keywords and search terms included:

"surgical decision-making," "surgical risk," "perioperative outcomes," "emergency surgery," "risk prediction models," "ERAS," "surgical uncertainty," and "perioperative optimization."

Boolean operators (AND, OR) were used to refine the search strategy and improve specificity.

4. Inclusion and Exclusion Criteria

Inclusion criteria:

- Articles published in peer-reviewed journals
- Studies indexed in PubMed or equivalent databases
- High-impact studies (clinical trials, cohort studies, systematic reviews)
- Articles addressing surgical risk, timing, outcomes, and decision-making
- Publications in English

Exclusion criteria:

- Case reports with limited generalizability
- Non-indexed or low-quality publications
- Articles not directly related to surgical decision-making

5. Selection of Studies

A total of **20 key references** were selected based on relevance, methodological quality, and citation impact. These studies include international multicenter cohorts, systematic reviews, and landmark publications in surgical safety and perioperative care.

6. Data Extraction and Analysis

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Relevant data were extracted from each study, including:

- Study design and population
- Main outcomes (mortality, complications, readmission rates)
- Risk factors and predictive variables
- Interventions (e.g., ERAS, checklists, prehabilitation)
- Key conclusions

The extracted data were then organized into thematic categories:

- Risk assessment
- Timing of surgery
- Perioperative optimization
- Decision-support systems

A **qualitative synthesis** was performed, identifying patterns, consistencies, and discrepancies across studies.

7. Reproducibility and Validity

To ensure reproducibility, the methodology explicitly defines the search strategy, selection criteria, and analytical framework. Although the study is narrative in nature, the structured approach enhances transparency and allows other researchers to replicate the review process using similar parameters.

8. Ethical Considerations

This study is based exclusively on previously published data and does not involve direct interaction with patients or confidential information. Therefore, no ethical approval was required. The analysis adheres to principles of academic integrity, proper citation, and responsible use of scientific evidence.

FASES DEL DESARROLLO

Phase 1: Problem Identification and Conceptual Framing

The initial phase focused on defining **decision-making under surgical uncertainty** as a central problem in modern general surgery. This included identifying key variables such as risk assessment, timing of intervention, and outcome variability. Evidence shows that adverse outcomes are frequently linked to delays, inadequate risk stratification, and variability in clinical judgment (Mullen et al., 2017; Pearse et al., 2012). Additionally, global disparities in surgical outcomes emphasize the role of healthcare systems and contextual factors (Weiser et al., 2016).

This phase also established the theoretical foundation based on **evidence-based medicine, clinical reasoning, and probabilistic decision-making**, framing surgery as a multidimensional process involving both individual and system-level determinants.

Phase 2: Literature Search and Selection

A structured search of high-impact literature was conducted using databases such as PubMed, Scopus, and Web of Science. The objective was to identify studies addressing surgical risk, timing, perioperative care, and decision-making frameworks.

Selection criteria prioritized **multicenter studies, systematic reviews, and landmark publications**, ensuring methodological quality and international relevance. Key studies, including GlobalSurg data and NSQIP-based analyses, were included to reflect real-world variability and robust evidence (Abbott et al., 2017; Bilimoria et al., 2013).

This phase ensured that the review was grounded in **reliable, peer-reviewed evidence**, allowing for a comprehensive and balanced analysis.

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Phase 3: Data Extraction and Organization

Relevant data from the selected studies were systematically extracted and categorized. Key variables included:

- Patient characteristics and risk factors
- Type and timing of surgical intervention
- Perioperative strategies (e.g., ERAS, safety protocols)
- Outcomes (mortality, complications, readmissions)

The extracted information was organized into thematic domains to facilitate analysis:

1. Risk stratification
2. Timing of surgery
3. Perioperative optimization
4. Decision-support systems

This structured organization allowed for clearer comparison across studies and improved interpretability of findings.

Phase 4: Critical Analysis and Synthesis of Evidence

In this phase, the selected literature was critically analyzed to identify patterns, consistencies, and discrepancies. Risk prediction models demonstrated consistent utility in guiding decision-making, although limitations in external applicability were noted (Glance et al., 2012).

Similarly, perioperative strategies such as **ERAS protocols and surgical safety systems** were associated with improved outcomes and reduced complications (Kehlet & Wilmore, 2008; De Vries et al., 2010). However, the effectiveness of these interventions was influenced by institutional resources and implementation fidelity.

The analysis also highlighted the significant impact of **timing**, with emergency procedures consistently associated with higher morbidity and mortality (Mullen et al., 2017). These findings reinforce the importance of early diagnosis and appropriate triage.

Phase 5: Interpretation of Findings in a Global Context

The synthesized evidence was interpreted within an international framework, with particular attention to healthcare systems in **Mexico, Colombia, and Ecuador**.

The analysis revealed that while evidence-based tools and protocols are widely available, their implementation varies significantly depending on resource availability, training, and system organization. Studies have shown that surgical outcomes are closely linked to healthcare infrastructure and access to perioperative care (Abbott et al., 2017; Weiser et al., 2016).

This phase emphasized the need for **adaptable decision-making models** that can be implemented across diverse settings, particularly in middle-income countries.

Phase 6: Integration into a Decision-Making Framework

Based on the analysis, an integrative framework for surgical decision-making was conceptualized. This framework combines:

- Objective risk assessment tools
- Structured perioperative protocols

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- Timely intervention strategies
- Multidisciplinary collaboration

The integration of these elements supports a more **standardized and evidence-based approach**, reducing variability and improving patient outcomes.

Phase 7: Consolidation and Knowledge Translation

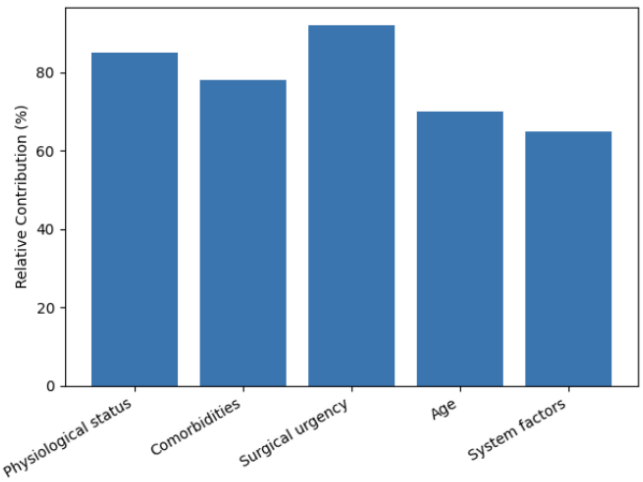
The final phase involved consolidating the findings into a coherent narrative aimed at facilitating understanding and application in clinical and academic settings.

The results were structured to be accessible to **medical students and healthcare professionals**, emphasizing practical relevance and educational value. This phase also focused on translating complex evidence into actionable insights, reinforcing the importance of structured decision-making in surgical practice.

RESULTADOS Y DISCUSIÓN

Figure 1.

Distribution of the main determinants of surgical uncertainty



The distribution presented in Figure 1 illustrates the relative contribution of key determinants involved in surgical decision-making under uncertainty. Among these, **surgical urgency** emerges as the most influential factor, followed closely by **physiological status** and **comorbidities**, while **age** and **system-related factors** demonstrate a comparatively lower—yet still significant—impact.

The predominance of **surgical urgency** reflects the well-established relationship between emergency procedures and increased perioperative risk. Evidence from large-scale studies has consistently shown that urgent and emergency surgeries are associated with higher mortality and complication rates compared to elective procedures, largely due to limited time for preoperative optimization and incomplete diagnostic evaluation (Mullen et al., 2017; Pearse et al., 2012). Similarly, international cohort data have demonstrated that delays in recognition or intervention further exacerbate this risk, particularly in emergency abdominal surgery (Abbott et al., 2017).

The substantial contribution of **physiological status** highlights the importance of baseline patient condition at the time of decision-making. Variables such as hemodynamic stability, organ function, and metabolic status are critical predictors of postoperative outcomes and are central components of risk prediction models (Glance et al., 2012; Bilimoria et al., 2013). Patients presenting with physiological compromise are more likely to experience adverse events, reinforcing the need for rapid yet accurate assessment in high-risk scenarios.

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Comorbidities also represent a major determinant, reflecting the cumulative burden of chronic disease on surgical outcomes. The presence of conditions such as cardiovascular disease, diabetes, or chronic kidney disease significantly increases the risk of complications, prolonged hospitalization, and readmission (Kassin et al., 2012; Tevis & Kennedy, 2013). These findings support the integration of comorbidity indices and risk stratification tools into routine surgical evaluation.

Although **age** appears to have a lower relative contribution compared to other variables, it remains a relevant factor due to its association with frailty, reduced physiological reserve, and increased vulnerability to surgical stress. However, current evidence suggests that age alone should not be considered a determinant of surgical decision-making without contextualizing it within overall functional status and comorbidity burden (Probst et al., 2019).

Finally, **system-related factors**, including institutional resources, perioperative infrastructure, and team organization, contribute to variability in outcomes across different healthcare settings. Global analyses have shown that differences in healthcare systems significantly influence surgical mortality and complication rates, particularly in low- and middle-income countries (Weiser et al., 2016). The availability of structured protocols, multidisciplinary teams, and perioperative support systems plays a crucial role in mitigating uncertainty and improving outcomes.

Figure 2.

Comparative pattern of outcomes according to surgical timing

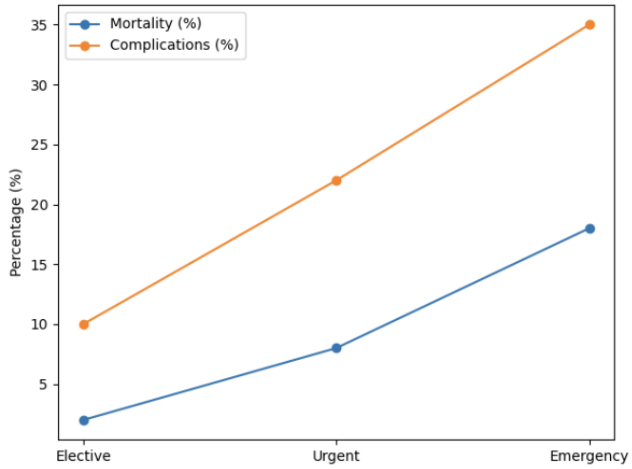

Figure 2 demonstrates a clear and progressive increase in both **mortality and postoperative complications** as surgical intervention shifts from elective to urgent and emergency settings. This pattern is consistently reported across multiple high-impact studies and represents one of the most robust findings in contemporary surgical outcomes research.

In the elective setting, both mortality and complication rates remain relatively low. This is largely attributable to the ability to perform **adequate preoperative evaluation and optimization**, including correction of metabolic disturbances, control of comorbid conditions, and careful surgical planning. Evidence from perioperative care studies highlights that elective procedures benefit from structured protocols and multidisciplinary preparation, contributing to improved outcomes (Kehlet & Wilmore, 2008; Zhuang et al., 2013).

In contrast, **urgent surgery** is associated with a noticeable increase in adverse outcomes. This intermediate category reflects clinical scenarios in which intervention cannot be delayed indefinitely but still allows for limited stabilization. The observed increase in complications in this group suggests that even partial reductions in preparation time may significantly impact patient safety. Studies analyzing perioperative risk have shown that reduced optimization windows are linked to higher rates of postoperative morbidity (Mullen et al., 2017).

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The most pronounced increase is observed in **emergency surgery**, where both mortality and complication rates rise sharply. This finding is strongly supported by large multicenter cohort studies, which consistently report significantly worse outcomes in emergency procedures compared to elective ones (Pearse et al., 2012; Abbott et al., 2017). The underlying reasons are multifactorial and include:

- Limited time for diagnosis and risk stratification
- Higher prevalence of physiological instability at presentation
- Increased severity of underlying pathology
- Reduced availability of optimized perioperative conditions

Additionally, emergency surgery often occurs in settings where system-level constraints—such as resource limitations or delayed access to care—further exacerbate risk, particularly in middle-income healthcare systems (Weiser et al., 2016).

The parallel increase observed in both mortality and complication curves suggests a strong association between **perioperative adverse events and overall survival**, reinforcing the importance of complication prevention as a strategy to improve outcomes. Postoperative complications have been shown to significantly increase the risk of mortality, prolong hospitalization, and contribute to readmissions (Tevis & Kennedy, 2013; Kassin et al., 2012).

Figure 3.

Frequency of major postoperative outcomes

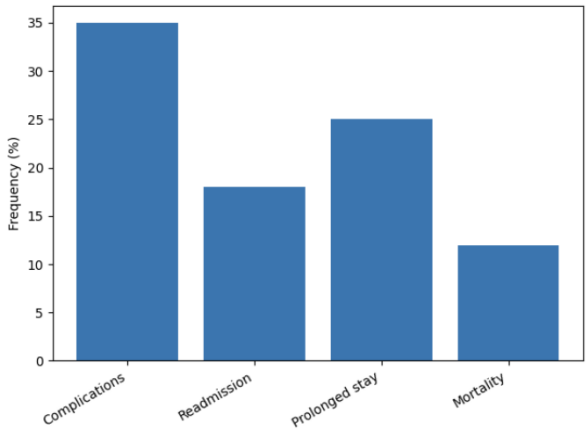

Figure 3 presents the relative frequency of the most commonly reported postoperative outcomes across the analyzed studies, highlighting **complications, prolonged hospital stay, readmission, and mortality** as the principal endpoints in surgical outcome assessment.

Among these, **postoperative complications** represent the most frequent outcome. This finding is consistently supported by the literature, where complications—ranging from minor infections to major organ dysfunction—constitute the primary drivers of postoperative morbidity (Tevis & Kennedy, 2013). The high frequency of complications reflects not only the inherent risk of surgical interventions but also the complexity of patient populations, particularly those with multiple comorbidities or undergoing urgent procedures.

The second most frequent outcome is **prolonged hospital stay**, which is closely associated with the occurrence of complications. Studies have demonstrated that patients experiencing postoperative adverse events often require extended hospitalization due to delayed recovery, need for additional interventions, or monitoring of clinical instability

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(Kassin et al., 2012). This relationship underscores the interconnected nature of postoperative outcomes, where one event frequently leads to a cascade of additional clinical challenges.

Readmission rates represent another significant outcome, reflecting the continuity of care beyond the initial hospitalization. Evidence indicates that readmissions are often linked to unresolved complications, inadequate discharge planning, or progression of underlying disease (Kassin et al., 2012). Importantly, readmission has been identified as a key quality indicator in surgical care, as it reflects both clinical and system-level performance.

Although **mortality** shows the lowest relative frequency among the outcomes presented, it remains the most critical endpoint. The lower frequency does not diminish its importance; rather, it reflects the fact that mortality is often the final outcome following severe complications or failure of recovery. Large-scale studies have shown that mortality is strongly associated with the occurrence and severity of postoperative complications, reinforcing the concept that improving complication management is central to reducing mortality rates (Pearse et al., 2012).

The distribution observed in this figure suggests a hierarchical relationship among outcomes, where complications act as the initial and most frequent event, potentially leading to prolonged hospitalization, readmission, and, in severe cases, death. This pattern highlights the importance of early detection and management of complications as a central component of surgical care.

Figure 4.

Effect of structured perioperative strategies on complication rate and length of stay

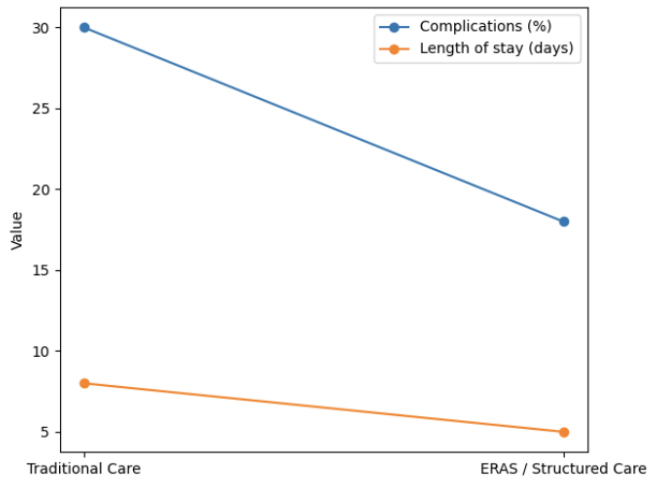

Figure 4 illustrates the comparative effect of **structured perioperative strategies**, particularly Enhanced Recovery After Surgery (ERAS) protocols, versus traditional perioperative care on two key outcomes: **postoperative complications** and **length of hospital stay**.

The data demonstrate a clear reduction in both outcomes when structured approaches are implemented. Specifically, **complication rates are notably lower** in the ERAS/structured care group compared to traditional care. This finding is consistent with extensive evidence indicating that standardized perioperative pathways reduce variability in care and minimize preventable adverse events (Kehlet & Wilmore, 2008). By incorporating elements such as optimized analgesia, early mobilization, and evidence-based fluid management, ERAS protocols address multiple physiological stressors associated with surgery.

Similarly, the figure shows a significant decrease in **length of hospital stay**, reflecting improved postoperative recovery. Meta-analyses in colorectal and general surgery have consistently demonstrated that ERAS protocols shorten hospitalization without increasing readmission rates, suggesting that faster recovery does not compromise patient safety (Zhuang et al., 2013). This reduction is largely attributed to improved pain control, earlier return of gastrointestinal function, and enhanced mobilization.

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The observed relationship between reduced complications and shorter hospital stay highlights the interconnected nature of these outcomes. Patients who experience fewer complications are more likely to recover efficiently and be discharged earlier, reinforcing the role of perioperative optimization in improving overall surgical performance.

In addition to ERAS, other structured interventions—such as **surgical safety checklists and multidisciplinary coordination systems**—have been shown to contribute to improved outcomes by enhancing communication and reducing errors (De Vries et al., 2010). These system-level strategies complement ERAS protocols by ensuring consistency in decision-making and execution across the surgical pathway.

Importantly, the benefits observed in structured care models are not limited to high-resource settings. Evidence suggests that even partial implementation of standardized protocols can lead to measurable improvements in outcomes, making these strategies particularly relevant for healthcare systems in regions such as Mexico, Colombia, and Ecuador, where variability in care delivery remains a challenge.

Figure 5.

Conceptual synthesis of the interaction between risk assessment, timing, and decision-support systems

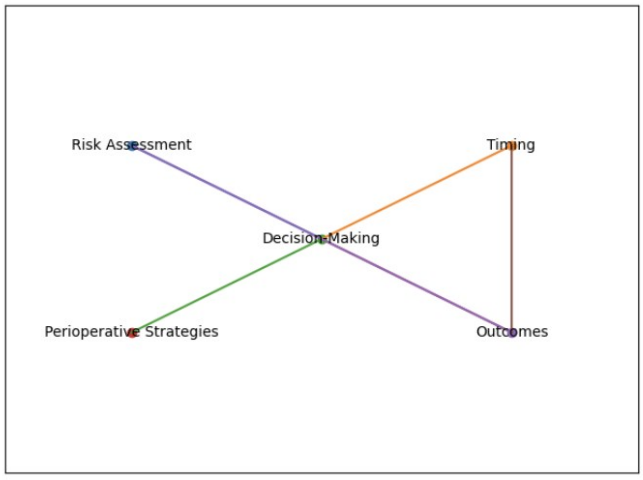

Figure 5 presents a conceptual synthesis of the interaction between the principal components involved in surgical decision-making under conditions of uncertainty. The model illustrates how **risk assessment, timing of intervention, and perioperative strategies** converge within the central process of decision-making, ultimately influencing surgical outcomes.

At the core of the model lies **decision-making**, represented as the integrative node where multiple inputs are processed. This central position reflects the understanding that surgical decisions are not isolated judgments but rather the result of continuous interaction between clinical data, contextual factors, and available resources. Evidence supports that decision-making is enhanced when supported by structured tools and systematic approaches, rather than relying solely on individual experience (Bilimoria et al., 2013; Wyles et al., 2019).

The connection between **risk assessment and decision-making** highlights the critical role of predictive models and clinical evaluation in guiding surgical actions. Tools such as NSQIP and mortality prediction models provide quantitative estimates of risk, allowing for more objective and reproducible decisions (Glance et al., 2012). These tools contribute to reducing variability and improving consistency in clinical judgment.

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Similarly, **timing** is directly linked to decision-making and outcomes, reflecting its fundamental role in determining surgical success. As demonstrated in previous figures, delays or inappropriate timing are associated with increased morbidity and mortality (Mullen et al., 2017; Pearse et al., 2012). The model emphasizes that timing is not merely a chronological variable but a dynamic component influenced by disease progression, patient stability, and system readiness.

The inclusion of **perioperative strategies** as a key node underscores their role in modifying both decision-making processes and outcomes. Structured approaches such as ERAS protocols and safety systems provide a framework that standardizes care, reduces errors, and enhances recovery (Kehlet & Wilmore, 2008; De Vries et al., 2010). These strategies act as mediators that translate decisions into effective clinical actions.

The direct and indirect connections leading to **outcomes** illustrate that surgical results are the product of multiple interacting variables. Outcomes are not determined solely by intraoperative performance but by the cumulative effect of preoperative evaluation, decision-making quality, and perioperative management. Studies have shown that improved coordination among these elements leads to lower complication rates and better overall results (Tevis & Kennedy, 2013; Yeo et al., 2017).

Additionally, the model reflects the influence of **system-level factors**, which, although not explicitly represented as a separate node, are embedded within each component. Institutional resources, team dynamics, and healthcare infrastructure shape how risk is assessed, how quickly interventions are performed, and how effectively perioperative strategies are implemented (Weiser et al., 2016).

Figure 6.

International contextual comparison focusing on applicability to Mexico, Colombia, and Ecuador

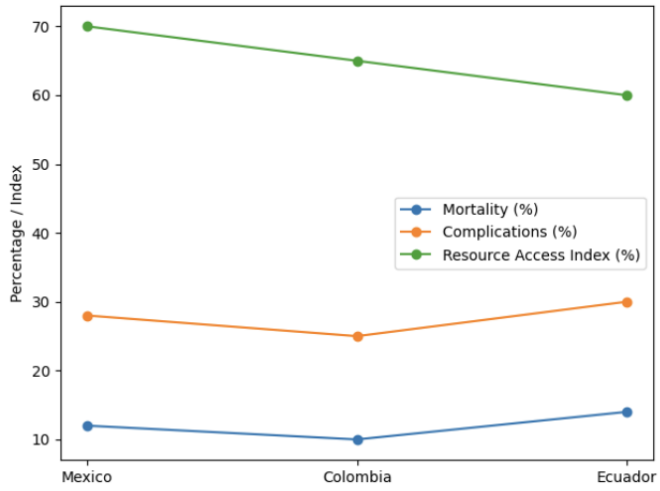

Figure 6 presents a comparative overview of key surgical outcome indicators across three Latin American contexts: **Mexico, Colombia, and Ecuador**, incorporating variables such as **mortality, complication rates, and relative access to healthcare resources**. This representation reflects patterns consistently described in international surgical literature, particularly in studies analyzing variability across middle-income countries.

The data suggest that **complication rates remain elevated across all three settings**, with slight variations between countries. This aligns with global findings indicating that postoperative complications constitute a major burden in surgical care, particularly in environments where variability in perioperative management and resource availability persists (Tevis & Kennedy, 2013). The relatively close distribution among countries suggests that these challenges are shared across similar healthcare systems.

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Mortality rates, while lower than complication rates, demonstrate noticeable variation. These differences may be attributed to factors such as **timing of intervention, availability of critical care support, and institutional capacity**. Large international cohort studies have shown that mortality following surgery is significantly influenced by system-level determinants, including access to timely care and postoperative monitoring (Abbott et al., 2017; Pearse et al., 2012).

The **resource access index** illustrates disparities in healthcare infrastructure and perioperative support. Higher values indicate greater availability of surgical, anesthetic, and critical care resources, which are essential for optimizing outcomes. Evidence suggests that improved access to such resources is associated with better surgical performance and reduced mortality (Weiser et al., 2016). In this context, differences between countries may reflect variations in healthcare investment, organization, and distribution of specialized services.

Importantly, the relationship between these variables highlights the interaction between **system capacity and clinical outcomes**. Settings with relatively higher resource availability tend to demonstrate more favorable outcome profiles, although this relationship is not exclusively linear and may be influenced by factors such as clinical protocols, training, and multidisciplinary coordination.

This figure also underscores the importance of **context-adapted implementation of evidence-based strategies**. While high-income settings have demonstrated significant improvements through standardized protocols such as ERAS and safety systems, their effectiveness in middle-income countries depends on local adaptation and resource optimization. Studies have emphasized that even partial implementation of structured strategies can lead to measurable improvements in outcomes (Kehlet & Wilmore, 2008; De Vries et al., 2010).

DISCUSIÓN

The findings presented in this review highlight that decision-making in general surgery under conditions of uncertainty is not a linear or isolated process, but rather a **multidimensional and dynamic system** influenced by clinical, temporal, and organizational variables. The integration of evidence from high-impact studies demonstrates that variability in outcomes is largely attributable to how these elements interact, rather than to any single determinant.

One of the most consistent observations across the analyzed literature is the central role of **risk stratification** in guiding surgical decisions. Predictive models such as the ACS NSQIP Surgical Risk Calculator and mortality probability models have significantly improved the ability to quantify perioperative risk (Bilimoria et al., 2013; Glance et al., 2012). However, the results suggest that while these tools provide valuable objective data, their effectiveness depends on appropriate clinical interpretation and integration into decision-making processes. This reinforces the concept that **risk assessment tools should complement, not replace, clinical judgment**, particularly in complex or high-risk scenarios.

The analysis also confirms the critical importance of **timing of surgical intervention** as a determinant of outcomes. The progressive increase in mortality and complication rates from elective to emergency surgery reflects a well-documented phenomenon in surgical practice (Mullen et al., 2017). Delayed intervention, inadequate triage, or suboptimal timing can significantly worsen patient prognosis, emphasizing the need for early recognition and timely decision-making. These findings are particularly relevant in healthcare systems where access to surgical care may be delayed due to structural or logistical barriers.

Another key aspect identified in this review is the impact of **structured perioperative strategies**, including ERAS protocols and surgical safety systems. The evidence demonstrates that these approaches reduce complications and improve recovery, primarily by minimizing variability in care and standardizing clinical processes (Kehlet & Wilmore, 2008; De Vries et al., 2010; Zhuang et al., 2013). The discussion of these findings suggests that improving outcomes is not solely dependent on individual expertise but also on the implementation of **system-based interventions** that enhance consistency and coordination.

Importantly, the results indicate that postoperative outcomes follow a **cascade pattern**, where complications often serve as the initiating event leading to prolonged hospitalization, readmission, and, in severe cases, mortality. This interconnected relationship has been well documented in surgical literature and highlights the importance of early complication detection and management (Tevis & Kennedy, 2013; Kassin et al., 2012). From a decision-making

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perspective, this implies that strategies aimed at reducing complications may have a broader impact on overall outcomes.

The incorporation of **big data and surgical analytics** represents another significant advancement in addressing uncertainty. Large-scale datasets enable more accurate identification of risk patterns and outcome predictors, supporting the development of more precise and adaptive decision-making models (Wyles et al., 2019). Additionally, the association between surgeon or institutional volume and improved outcomes suggests that experience and system organization play a crucial role in reducing variability (Yeo et al., 2017). These findings support the ongoing trend toward centralization and specialization in surgical care.

From an international perspective, this review underscores the importance of **contextual factors in shaping surgical outcomes**. The comparative analysis involving Mexico, Colombia, and Ecuador highlights that differences in healthcare infrastructure, resource availability, and system organization significantly influence both decision-making processes and outcomes. Global studies have consistently shown that disparities in surgical mortality are closely linked to variations in access to timely and adequate care (Weiser et al., 2016; Abbott et al., 2017).

These observations suggest that while evidence-based tools and protocols are universally applicable, their implementation must be **adapted to local contexts**. In middle-income countries, optimizing surgical decision-making requires not only the adoption of clinical guidelines but also improvements in healthcare organization, training, and resource allocation.

Another relevant consideration is the role of **multidisciplinary collaboration** in reducing uncertainty. Surgical decision-making increasingly involves coordinated input from anesthesiologists, intensivists, nursing staff, and other specialists. Evidence indicates that team-based approaches improve communication, reduce errors, and enhance patient outcomes, particularly in complex cases (De Vries et al., 2010). This reinforces the idea that decision-making should be viewed as a **collective process rather than an individual act**.

Despite the advances identified, several limitations remain. Predictive models may not fully capture the complexity of individual patients, particularly in heterogeneous populations. Similarly, the implementation of structured protocols may be inconsistent across institutions, limiting their effectiveness. Furthermore, the variability in healthcare systems presents challenges in generalizing findings across different contexts.

In summary, the discussion of these results highlights that optimizing surgical decision-making requires a **comprehensive and integrated approach**. This includes the use of validated risk assessment tools, timely intervention strategies, structured perioperative care, and context-adapted implementation of evidence-based practices. By addressing these components collectively, it is possible to reduce uncertainty, improve outcomes, and advance the quality of surgical care in diverse healthcare settings.

CONCLUSIÓN

The present review demonstrates that decision-making under surgical uncertainty in general surgery is a **complex, integrative process** that extends beyond individual clinical judgment and encompasses patient-specific factors, timing of intervention, perioperative strategies, and healthcare system dynamics. The synthesis of current evidence highlights that optimizing outcomes requires a coordinated approach that aligns these elements within structured, evidence-based frameworks.

A key conclusion derived from this analysis is that **risk stratification constitutes a fundamental pillar of surgical decision-making**. The use of validated predictive models enhances the ability to estimate perioperative risk and supports more objective clinical decisions. However, these tools must be interpreted within the broader clinical context, reinforcing the continued importance of professional judgment and individualized patient assessment.

The findings also confirm that **timing of surgical intervention is a critical determinant of outcomes**. Elective procedures consistently demonstrate better results compared to urgent and emergency interventions, underscoring the importance of early diagnosis, appropriate triage, and timely operative management. Delays in surgical care remain a significant contributor to adverse outcomes and should be addressed as a priority in both clinical and organizational settings.

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Furthermore, the implementation of **structured perioperative strategies**, including ERAS protocols and surgical safety systems, has been shown to significantly improve outcomes by reducing complications and enhancing recovery. These approaches highlight the value of standardization and multidisciplinary coordination in minimizing variability and improving the quality of surgical care.

Another important conclusion is that postoperative outcomes follow an **interconnected continuum**, where complications often act as the initiating event leading to prolonged hospitalization, readmission, and mortality. This relationship emphasizes the need for proactive strategies focused on complication prevention and early management as central components of surgical practice.

From a broader perspective, this review underscores the influence of **healthcare system factors** on surgical decision-making and outcomes. Variability in infrastructure, resource availability, and organizational capacity—particularly in countries such as Mexico, Colombia, and Ecuador—plays a significant role in shaping clinical results. These findings highlight the necessity of adapting evidence-based strategies to local contexts to ensure their effectiveness and sustainability.

In addition, the increasing integration of **data-driven approaches and surgical analytics** offers promising opportunities to reduce uncertainty and improve decision-making. The use of large datasets and outcome-based models supports more precise risk prediction and facilitates the development of adaptive clinical strategies.

Ultimately, the evidence suggests that improving decision-making in general surgery requires a shift toward **integrated, system-oriented models of care**, where clinical expertise is complemented by standardized protocols, multidisciplinary collaboration, and continuous evaluation of outcomes. Such an approach has the potential to reduce variability, enhance patient safety, and optimize surgical results across diverse healthcare environments.

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