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Comparative Effectiveness of Emergency Department Triage Systems Across Patient Volume and Resource Contexts: A Systematic Review

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Abstract *Introduction: The primary objective of triage in the Emergency Department (ED) is the early identification of time-sensitive patients, appropriate allocation of resources, and safe decision-making under crowding conditions.[1,2] The performance of triage systems may vary depending on the clinical environment in which they are implemented, patient flow, resource availability, staff training, and electronic audit capabilities. [30,31]*

Keywords: Triage; Emergency Service, Hospital; Emergency Department; Patient Acuity; Crowding; Hospitalization; Intensive Care Units; Mortality; Systematic Review.

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1. Introduction

Triage is not merely the entry point of the Emergency Department (ED) but a critical decision node shaping the clinical and operational patient flow of the entire department.[4] As ED crowding increases, inpatient bed availability decreases, and staff cognitive load rises, the quality of initial prioritization becomes associated with time-to-physician, hospital admission rates, delays in critical interventions, and mortality. [30,31]

Although modern in-hospital triage systems share the same overarching goal, they differ in their underlying logical architecture.[1,2] The Emergency Severity Index (ESI) prioritizes patient stability, immediate life-threatening risk, and anticipated resource utilization.[1] The Manchester Triage System (MTS), Canadian Triage and Acuity Scale (CTAS), and Australasian Triage Scale (ATS) are primarily complaint- and discriminator-based systems with structured time-to-assessment targets.[2,3] The South African Triage Scale (SATS) integrates physiological scoring with clinical discriminators, providing a simplified, high-sensitivity-oriented model.[3] The Korean Triage and Acuity Scale (KTAS) is a nationally implemented system derived from CTAS and adapted to the Korean healthcare context. [5]

While recent systematic reviews have characterized the overall performance of triage systems, comparative syntheses oriented toward practical decision-making across variables such as patient flow, resource availability, hospital type, public versus private sector burden, and geriatric patient predominance remain limited. [1-4]

The objective of this systematic review is to address this gap by providing a contextual synthesis of major ED triage systems in relation to clinical outcomes, operational performance metrics, and safety trade-offs across diverse patient volumes and resource settings.

2. Methods

This review was conducted as a systematic review with a structured narrative synthesis in accordance with PRISMA 2020 guidelines. The primary clinical question was defined as follows: “In the context of diverse patient volumes and resource settings, which in-hospital emergency department (ED) triage system appears most appropriate and safest in terms of clinical and operational outcomes?”

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PICOS framework

Element	Definition
Population	Adult or mixed-age patients present to in-hospital emergency departments (EDs), including specific subgroups of older adult and trauma patients.
Index systems	ESI, MTS, CTAS, ATS, SATS and KTAS.
Comparator	Other triage systems; different levels of urgency within the same system; pre- and post-implementation conditions; and cross-context comparisons.
Outcomes	Under-triage, over-triage, mortality, ICU admission, hospitalization, time-to-physician, emergency department length of stay (ED LOS), left without being seen (LWBS), crowding metrics, resource utilization, and inter-rater reliability.
Study design	Prospective and retrospective cohorts, cross-sectional validation studies, and before-after implementation studies; systematic reviews and meta-analyses were utilized separately for knowledge gap analysis and contextual interpretation.

Search strategy and study selection process.

An initial search was conducted across PubMed/MEDLINE, Embase, Scopus, Web of Science, and the Cochrane Library databases, with an updated verification completed on May 25, 2026. The search prioritized the evidence base of the last 10 years; however, earlier studies considered pivotal from methodological and contextual perspectives were also included. Reference lists were manually screened to identify additional eligible sources.

A sample search string was constructed as follows: (“Emergency Severity Index” OR ESI OR “Manchester Triage System” OR MTS OR CTAS OR ATS OR SATS OR KTAS OR “Canadian Triage and Acuity Scale” OR “Australasian Triage Scale” OR “South African Triage Scale” OR “Korean Triage and Acuity Scale”) AND (“emergency department” OR “Emergency Service, Hospital”) AND (validity OR reliability OR under-triage OR over-triage OR mortality OR hospitalization OR ICU OR crowding OR “length of stay” OR “time to physician” OR “resource utilization”).

Systematic reviews and meta-analyses were utilized not as primary outcome units, but to map the existing evidence base, identify knowledge gaps, and for contextual interpretation of the findings.[1–5] Conversely, original studies served as the

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primary unit of analysis for synthesizing system-specific performance, hospital types, resource levels, geriatric patient subgroups, trauma, and implementation outcomes.

The search and selection process was summarized in accordance with the PRISMA 2020 guidelines. A total of 142 records were identified through structured databases and reference lists; after removing duplicates, 98 records were screened based on title and abstract. Forty-seven full-text articles were assessed for eligibility, of which 16 were excluded due to irrelevant context, overlapping cohorts, case-scenario designs, or insufficient outcome data. Ultimately, 31 sources were included in the final narrative synthesis: 6 systematic/scoping reviews and 25 original validation, comparative, or implementation studies.

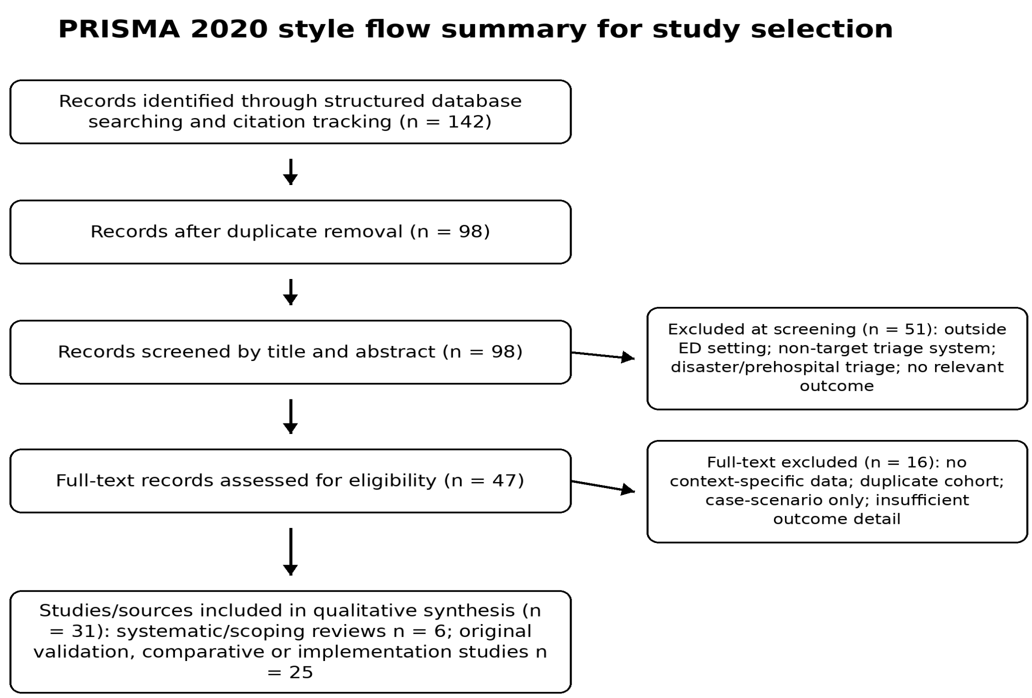

Figure 1. Study selection flow diagram in accordance with PRISMA 2020 guidelines.

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Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Studies evaluating at least one of the six target systems.	Prehospital triage, disaster triage, and military triage systems.
Studies reporting clinical or operational outcomes within the ED.	Studies evaluating only educational interventions without reporting clinical or operational outcomes.
Studies providing inter-system or setting-specific comparative data.	Local, non-standard tools outside the six target systems.
Studies providing subgroup analyses by elderly, trauma, university, regional, LMIC, or resource-limited settings.	Studies focused on a single condition that do not represent general ED triage.
Systematic reviews and meta-analyses for identifying knowledge gaps and evidence mapping.	Conference abstracts, non–peer-reviewed materials, and records without full-text availability.

Data extraction and contextual classification

For each study, data were extracted on country, setting, study design, sample size, evaluated triage system, primary outcome, geriatric and trauma subgroups, hospital type, resource level, and key findings. Contextual categories were defined based on annual emergency department volume, hospital type, ICU and subspecialty availability, digital triage integration, the authors' description of the setting, and the classification of the system within LMIC or HIC contexts. This classification was not a formal meta-regression, but rather a structured interpretative framework used to construct a narrative decision matrix.

Risk of Bias and Certainty of Evidence

Observational comparative and implementation studies were evaluated using the ROBINS-I tool, while classical cohort validation studies were assessed using the Newcastle-Ottawa Scale (NOS). Because systematic reviews were used as a contextual evidence map, their findings were interpreted primarily in terms of methodological relevance, search comprehensiveness, and heterogeneity. Outcome-specific certainty of evidence was synthesized using the GRADE framework and categorized as "moderate," "low," and "very low." Due to the lack of randomized head-to-head trials, heterogeneity in outcome definitions, and risk of

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confounding, the overall certainty of evidence was conservatively rated. A formal meta-analysis was not performed due to substantial heterogeneity in outcomes and reference standards, varying definitions of triage levels, and cross-contextual measurement discrepancies. [25,26]

Summary of Included Key Studies

Author/Year	Design	Context	System	Primary outcome	Key message of the review
Hinson et al., 2019	Systematic review	Multi-country	Various systems	Triage performance	Mapped the overall evidence base; performance variability is high.
Zachariasse et al., 2019	Systematic review/meta-analysis	Multi-country	CTAS, ESI, MTS and others	High/low urgency	The validity of the systems is moderate to good, but performance is highly variable.
Jenson et al., 2018	Systematic review	LMIC	ED triage tools	Reliability/validity	In LMIC settings, the validity of the tools is variable; practical implementation is essential.
Mitchell et al., 2023	Systematic review	LMIC	Triage implementation	Clinical/process outcomes	Triage implementation may improve early

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Author/Year	Design	Context	System	Primary outcome	Key message of the review
					mortality and waiting time indicators
Sax et al., 2023	Retrospective multicenter cohort	USA	ESI	Mis-triage	For ESI, mis-triage remains significant; under-triage is low, while over-triage is high.
Hinson et al., 2018	Retrospective cohort	Brazil	ESI	Under/over-triage	Age and vital sign abnormalities are associated with under-triage.
van Wegen et al., 2025	Observational multicenter	Netherlands	ESI, MTS, NTS	Admission/mortality/resource use	ESI appears safer in identifying low-acuity cases.
Zachariasse et al., 2017	Prospective cohort	Europe	MTS	Validity	Performance is reduced in pediatric and elderly populations.
Steiner et al., 2016	Prospective cohort	Switzerland	MTS	Adverse outcomes	The MTS is useful in adult medical ED patients, but not perfect.
Lee et al., 2011	Cohort	Korean/Canadian system	CTAS	Resource/life-saving intervention	In elderly ED patients, CTAS

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Author/Year	Design	Context	System	Primary outcome	Key message of the review
					predicts resource utilization and the need for critical interventions.
Davis et al., 2022	Retrospective cohort	Canada	CTAS	Admission/ICU/death	Removal of the pain component did not worsen primary outcome prediction.
Ebrahimi et al., 2015	Meta-analysis	Multi-country	ATS	Reliability	ATS reliability is acceptable, but with high heterogeneit.
Wangara et al., 2019	Before-after implementation	Kenya	SATS	Agreement/sensitivity/specificity	High sensitivity, but high over-triage; training improves performance.
Meyer et al., 2018	Validation study	South Africa	SATS	Validity rural hospital	SATS can be applied in resource-limited rural settings.
Choi et al., 2019	National data analysis	Korea	KTAS	Urgency validity	High sensitivity, modest specificity.

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Author/Year	Design	Context	System	Primary outcome	Key message of the review
Kwon et al., 2018	Observational	Korea	KTAS	Admission/disposition/mortality/LOS	KTAS is associated with outcomes.
Moon et al., 2019	Review/expert comparison	Korea	KTAS	Mis-triage/kappa	Good inter-rater agreement, but mis-triage persists.
Chung et al., 2023	Retrospective two-center study	Korea	KTAS	Older vs adult outcomes	Discrimination is reduced in elderly patients.
Zakeri et al., 2022	Comparative trauma study	İran	ESI vs MTS	Trauma LOS/admission	MTS may be superior in terms of length of stay, but safety outcomes are limited.

Risk of bias assessment

Study	Tool	Overall risk	Brief rationale
Sax et al., 2023	ROBINS-I	Moderate	Large multicenter real-world data; retrospective design and limitations of the reference standard.
Hinson et al., 2018	ROBINS-I	Moderate	The cohort is large; confounding and local system effects are possible.
van Wegen et al., 2025	ROBINS-I	Moderate	Multicenter head-to-head comparison is strong; residual confounding remains.
Zachariasse et al., 2017	ROBINS-I/NOS	Low to moderate	Prospective design; heterogeneity in age subgroups.

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Study	Tool	Overall risk	Brief rationale
Steiner et al., 2016	NOS	Moderate	Prospective adult medical cohort; single-system focus and limitations in outcome proxies.
Lee et al., 2011	NOS	Moderate	Clinically relevant outcomes for an elderly cohort; historical and setting-specific data.
Davis et al., 2022	ROBINS-I	Moderate	Large sample; intervention of a natural experiment type and retrospective analysis.
Wangara et al., 2019	ROBINS-I	Serious to moderate	Before–after design; high risk of confounding due to training and implementation effects.
Meyer et al., 2018	NOS	Moderate	Practical evidence for rural settings; single-center limitation.
Choi et al., 2019	ROBINS-I	Moderate	National data; limitations in outcome definition and specificity.
Kwon et al., 2018	ROBINS-I	Moderate	Outcome gradients are useful; residual confounding is possible.
Moon et al., 2019	ROBINS-I	Moderate	Comparison with expert review; sample and reviewer effects are possible.
Chung et al., 2023	ROBINS-I	Moderate	Strong sample for the elderly subgroup; retrospective design.
Zakeri et al., 2022	ROBINS-I	Serious to moderate	Useful for trauma, but limited by sample size and outcome power.

GRADE summary

Outcome	Primary systems	GRADE certainty of evidence	Primary reason
Hospitalization / disposition gradient	ESI, MTS, CTAS, KTAS	Moderate	Large cohort studies and consistent gradients are present; however, observational design and setting differences remain.
Mortality and ICU admission	ESI, MTS, KTAS, CTAS	Low to moderate	Clinically relevant, but rare outcomes, confounding, and

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Outcome	Primary systems	GRADE certainty of evidence	Primary reason
			differences in reference standards weaken the evidence.
Under-triage / over-triage	ESI, SATS, KTAS, MTS	Low	Definitions and gold standards are variable; expert panels and outcome proxies differ.
Interrater reliability	MTS, KTAS, CTAS, ATS	Low to moderate	Kappa/inter-rater agreement data are available, but they are influenced by case mix and training level.
Time-to-physician and ED LOS	MTS, ESI, SATS	Low	Operational outcomes are strongly influenced by local workflow and crowding.
Crowding, LWBS and sector comparison	Various	Very low	Direct comparative and standardized outcome data are very limited.
Performance in elderly patients	ESI, MTS, CTAS, KTAS	Low to moderate	A consistent decline is observed across several systems; however, geriatric-specific standards are heterogeneous.

3. Results

The existing evidence base was thematically categorized into five clusters: systematic reviews on overall performance; large multicenter comparative studies of ESI and MTS in high-resource settings; reliability and validity studies of CTAS and ATS; SATS studies from resource-limited African and other LMIC settings; and KTAS-based national data from Korea, including elderly subgroups. The main

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knowledge gap lies in the fact that published reviews have largely compared systems in a general manner, while decision-oriented stratification by patient flow, resource context, public–private burden, and hospital type remains limited. [1-5]

ESI

In high-volume, resource-rich systems, ESI appears to have the most extensive evidence base among triage systems.[6,12] In a cohort including 5,315,176 adult ED visits across 21 hospitals in the United States, the mis-triage rate was 32.2%, of which 3.3% represented under-triage and 28.9% over-triage.[6] This finding indicates that ESI provides a strong platform for resource prioritization but does not fully eliminate the problem of critical under-triage.

A multicenter observational study from the Netherlands compared ESI, MTS, and NTS and demonstrated that ESI was associated with lower hospitalization and in-hospital mortality rates in the lowest acuity category compared with MTS and NTS.[12] This finding suggests that ESI may be stronger in distinguishing between low- and high-acuity cases; however, this advantage should not be interpreted separately from setting- and implementation-related factors.

MTS

The overall validity of the MTS is rated as moderate to good, and its chief complaint- and discriminator-based, time-targeted structure provides operational transparency; however, while prospective multicenter studies show acceptable sensitivity and specificity in adults, its performance declines in pediatric and geriatric cohorts.[9-11] Although trauma center data suggest that the MTS may outperform the ESI in terms of emergency department length of stay (ED LOS), the evidence remains limited for drawing definitive conclusions regarding safety outcomes. [24]

CTAS and ATS

CTAS appears particularly useful for identifying resource utilization and immediate life-saving intervention needs in elderly ED patients; nonetheless, over the past decade, adult multicenter evidence directly comparing CTAS with ESI, MTS, or KTAS in terms of patient flow and resource context remains limited. [14,15] ATS is a reliable and well-established system, with meta-analytic data indicating an acceptable reliability profile; however, due to insufficiently robust contemporary adult comparative evidence, methodological caution is required before presenting it as a superior system in this contextual comparison. [17]

SATS

Regarding the SATS, it stands out as a practical choice for resource-limited and high-volume systems.[18,19] In an implementation and performance study conducted at Kenyatta National Hospital, expert agreement improved following a training intervention, and the system demonstrated high sensitivity but low

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specificity.[19] This profile reflects the SATS-specific trade-off between high sensitivity and high over-triage. In resource-constrained public sector settings, where not missing a critical patient is the primary priority, this trade-off can be clinically rationalized.

KTAS

For the KTAS, it demonstrates high sensitivity and good inter-rater agreement within a nationally implemented electronic system and a standardized training environment.[20,21] In Korean data, KTAS was associated with ED mortality, ICU admission, hospitalization, and length of stay (LOS).[21] However, its specificity is modest, and the decline in AUROC among elderly patients highlights the need for a geriatric modifier within the KTAS framework. [23]

Context-based synthetic decision matrix

Clinical context	Most appropriate system(s)	Primary reason	Primary caveat
High patient volume, resource-rich university/urban center	ESI; alternatively, KTAS/CTAS	Low–high acuity stratification, resource-oriented decision-making, and EHR compatibility	ESI III clustering, elderly under-triage, and need for audit.
High patient volume, resource-limited public-sector system	SATS	Simple implementation, high sensitivity, low-resource applicability	Over-triage may be high; continuous training and monitoring are essential.
Low to moderate patient volume, rule-based time-targeted prioritization	MTS or CTAS	Chief complaint- and discriminator-based structure with operational transparency	Performance may decline in elderly patients and in crowding conditions.
National Asian system with digital integration	KTAS	Alignment with national data, good kappa, and high sensitivity	Specificity is modest; discrimination is reduced in elderly patients.

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Clinical context	Most appropriate system(s)	Primary reason	Primary caveat
ED with high elderly patient burden	Core system + geriatric/frailty modifier	A relative performance decline is observed in elderly patients across all major systems.	An additional risk layer is needed for frailty, atypical presentation, and multimorbidity.
Trauma center	MTS or ESI	Signal of LOS advantage in MTS, extensive experience with ESI	Under-triage should be monitored through local hard-stop rules and audit.

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4. Discussion

The primary finding of this review is that the effectiveness of a triage system must be evaluated in conjunction with the clinical ecosystem in which it is deployed, rather than assessing the tool in isolation. The existing evidence does not support a universal "one-size-fits-all" or "best" system approach.[1,2] A more realistic strategy involves selecting an appropriate system based on hospital-specific patient volume, resource availability, sector type, staff training, and auditing capacity. [3,4]

ESI appears to have the strongest evidence base in high-volume, resource-rich emergency departments.[6,12] This advantage is primarily attributed to its early structuring of resource utilization and its relatively stable profile in differentiating between low- and high-acuity patients.[6] However, it must be considered that the ESI does not entirely resolve the mis-triage problem, and additional auditing is required, particularly in elderly populations and within the ESI-III category. [8,27]

The core strength of the MTS and CTAS lies in their clinical complaint-centered, clinically intuitive, and time-targeted structures.[9,10] In moderately busy emergency departments with strong organizational discipline and stable staff training, these systems may provide practical advantages for daily flow management. [14,15] Nonetheless, in high-volume systems, rule-based time targets alone may be insufficient, and the persistence of severe outcomes in lower-acuity categories must be closely monitored. [11]

The clinical philosophy of the SATS is distinct: its strength lies not in maximum specificity, but in not missing a critically ill patient—through high sensitivity and practical simplicity.[18,19] Therefore, establishing a safety margin at the expense of over-triage in resource-limited and high-volume public-sector systems can be a logical approach for the SATS.

The KTAS represents an important regional model demonstrating how triage performance can be enhanced through national digital integration and a standardized training ecosystem. [20,21] However, KTAS also exhibits a decline in performance among elderly patients. [23] This suggests that the issue is related not only to tool design but also to non-specific presentations, multimorbidity, and frailty in elderly patients, as well as the fact that vital sign changes are not always captured by classical cutoff values.

The successful implementation of a triage system does not depend solely on the structural characteristics of the selected tool. Initial and continuous staff training, real-time or periodic auditing mechanisms, electronic triage integration, feedback loops, local "hard stop" rules, leadership support, and bed management directly influence system performance.[4,19] The same triage tool may perform poorly in a department without training or auditing and with unmanaged

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crowding yet operate more safely in a department with standardized training and electronic decision support. [30,31]

The geriatric patient population provides the most consistent clinical signal in this review: major systems, including the ESI, MTS, CTAS, and KTAS, may exhibit a relative decline in performance among elderly patients.[5,8,23] Therefore, in emergency departments with a high geriatric patient burden, incorporating modifiers such as frailty, cognitive status, fall risk, polypharmacy, atypical presentation, and social vulnerability into the primary triage system represents a more practically safe approach.

The priority for future research should not be the question of "which system is globally superior?", but rather "which system minimizes harm and maximizes benefit under specific patient volumes, resource levels, and implementation models?". Consequently, there remains a critical need for head-to-head, multicenter, sector- and volume-stratified prospective studies in this field.

Limitations and quality of evidence

The primary limitation of this review is the methodological heterogeneity inherent in the included triage studies. There is no uniform gold standard for defining under-triage and over-triage; while some studies utilized expert panels, others relied on hospitalization, ICU admission, mortality, resource utilization, or composite endpoints.[25,26] These discrepancies weaken the validity of formal meta-analytic pooling.

Furthermore, a significant proportion of the evidence base consists of retrospective or single-center observational designs. Contemporary adult comparative evidence for ATS, recent head-to-head multicenter studies for CTAS, and direct data regarding public–private sectors, left without being seen (LWBS), and crowding outcomes remain limited. Because patient volume and resource levels are not consistently reported in a standardized manner across many studies, the contextual classification remains structured yet partially interpretative.

Consequently, the presented decision matrix should not be interpreted as a normative protocol, but rather as a contextual framework to support clinical and operational decision-making based on the existing evidence.

5. Conclusion

The synthesis of available evidence indicates that the selection of an ED triage system should be guided by the nature of the clinical context rather than the "most popular tool" principle. In high-volume, resource-rich academic or urban centers, ESI appears to be the option with the strongest evidence base.[12] Conversely, in resource-limited, high-volume public systems, the SATS may serve as a practical and safety-oriented option.[19] In moderately busy environments

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where rule-based time targets are prioritized, the MTS and CTAS represent suitable options. Within national systems featuring robust digital integration, the KTAS can function efficiently; meanwhile, although the ATS is a reliable system, contemporary comparative evidence remains limited to position it as a leading system in this contextual comparison. [23].

From a practical standpoint, the most critical conclusion is that in any ED with a high geriatric patient burden, the selected primary triage system must be supported by a geriatric modifier, a frailty layer, or a systematic post-triage audit. A triage tool is not merely an algorithm but a clinical management system that functions in tandem with training, electronic integration, auditing, and organizational support.

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