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ORIGINAL ARTICLE

Improving the Efficiency of the Patient Triage System Based on the Emergency Severity Index in the Outpatient and Emergency Departments, Samdet Hospital, Kalasin Province

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Abstract

This research and development study, combined with a one-group pretest-posttest quasi-experimental design, aimed to analyze the situation, develop, and evaluate a patient triage system based on the Emergency Severity Index (ESI) in the outpatient department and emergency room of Samdet Hospital, Kalasin Province, from January 2024 to September 2025. The participants comprised 24 triage personnel and 800 triage records (400 before and 400 after the development). The research instruments were the ESI-based triage system, a knowledge test, a triage competency assessment, a triage accuracy audit form, and a satisfaction questionnaire. Data were analyzed using descriptive statistics, paired t-test, Welch's t-test (Mann-Whitney U test for non-normal data), and chi-square test by outcome with GEE logistic regression adjusted for triage personnel, Holm-adjusted p values, and mean differences with 95% CI. Before the development, triage errors, both under-triage and over-triage, occurred in both departments and were attributed to the service system, personnel, and tools. After the development, the mean knowledge score increased from 11.41 ± 2.32 to 17.38 ± 1.71 and the mean triage competency score increased from 10.88 ± 2.56 to 16.55 ± 1.96 ($p < .001$). Triage accuracy increased from 82.00% to 93.00% (difference 11.00 percentage points, 95% CI 6.47-15.58) and under-triage decreased from 13.00% to 4.50% (difference 8.50 percentage points, 95% CI 4.64-12.50), whereas over-triage did not differ significantly (5.00% to 2.50%, $p = .063$). The mean waiting time to see a physician decreased from 41.37 to 27.45 minutes (difference 13.92 minutes, 95% CI 11.93-15.91; $d = 0.97$). Triage accuracy was higher, under-triage lower, and waiting time shorter after implementation of the developed system; however, with a one-group pretest-posttest design and no comparison group, causal effects and effects on patient safety cannot be concluded.

Keywords: triage, Emergency Severity Index, emergency service hospital, patient safety

Introduction

The outpatient and emergency departments are the front line of a hospital. The triage unit plays a vital role in assessing symptoms, classifying patients, prioritizing urgency, and referring patients correctly to the appropriate departments, and it is the starting point of safe, high-quality care.[1] The Emergency Medical Committee issued the Criteria for Emergency Triage Assessment and Emergency Operation Standards B.E. 2554 (2011), recommending five-level emergency triage[2] using the Emergency Severity Index (ESI), a United States standard that focuses on identifying critically ill patients and those at risk who require urgent care. This system used ESI version 4 because it is the version disseminated by the National Institute for Emergency Medicine and used for training in Thailand. The Emergency Nurses Association published ESI version 5 in 2023 with clarified algorithm wording;[3] version 5 should therefore be adopted in the next development cycle. The ESI also emphasizes smooth workflow to reduce emergency department crowding.[4,5] A standardized triage system gives nurses a common approach, speeds patient flow, reduces treatment delays for truly emergent patients, prevents avoidable deaths, reduces triage errors, and limits unnecessary resource use.[1,5] Nationally, the 1669 hotline received 8,180,908 calls in 2023, ranging from critically ill patients to general illnesses.[6]

Emergency departments of hospitals in Kalasin Province are front-line services operating 24 hours a day and require specialists to care for large numbers of patients.[7] Samdet Hospital serves an average of 400-700 outpatients per day. It introduced triage in 2015 and adopted five-level patient classification in 2016. In 2023, 1,378 patients attended the emergency room (patients served in the emergency room throughout 2023, separate from the 400-700 general outpatients per day; of these, 513 (37.23%) were ESI levels 1-3 and 865 (62.77%) were levels 4-5), classified by ESI as resuscitation (level 1), 16; emergent (level 2), 135; and urgent (level 3), 362 patients.[8] A review of risk reports revealed deterioration while waiting for examination, long triage times, high triage error rates, and frequent complaints from patients not treated according to urgency, because the triage guideline consisted only of broad criteria.[8]

Triage errors are of two types. Under-triage (in this study, an ESI level assigned by the triage personnel that is less urgent than the expert-assigned level by one level or more; over-triage means more urgent by one level or more, defined against the expert-assigned ESI level, with results reported separately for ESI levels 1-2, which have the highest clinical importance) delays diagnosis and treatment and may lead to deterioration, disability, or death, whereas over-triage deprives other critically ill patients of timely care, wastes resources, and causes emergency room overcrowding.[9] The ESI has high validity and reliability and is easy and quick to use;[10,11] however, triage results depend on the knowledge, skills, and training of the triage personnel,[9] and triage error rates vary widely among facilities.[12] In Thailand, the ESI is applicable in hospitals ranging from community to regional hospitals,[5] and effective triage is one of the patient safety goals of the 2P Safety policy.[13] Nevertheless, research developing a triage system that simultaneously addresses staffing structure, triage personnel, tools, and indicators in both the outpatient department and

the emergency room of small hospitals remains limited. Thai studies that developed ESI-based triage systems include a triage model for the emergency room of Khaowong Hospital, Kalasin Province, which reported 96.80% triage accuracy after development,[14] and a triage system for the accident and emergency departments of community hospitals in Phra Nakhon Si Ayutthaya Province;[15] however, these studies focused mainly on the emergency room and did not include the outpatient department.

In this context, the researcher improved the efficiency of the patient triage system of Samdet Hospital based on the ESI with the participation of a multidisciplinary team and evaluated outcomes in terms of triage accuracy, patient safety, and satisfaction. The findings are expected to provide the hospital with a unified triage model for both the outpatient department and the emergency room and to serve as a guide for hospitals in similar settings.

Conceptual framework and research hypotheses The study used Donabedian's structure-process-outcome framework.[16] Hypotheses: H1, the proportion of correct triage after the development is higher than before; H2, the proportion of under-triage after the development is lower than before; and H3, knowledge and competency scores after the development are higher than before, as shown in Figure 1.

Structure	Policy and multidisciplinary working group Staffing and qualifications of triage personnel (no triage by porters) Triage tools and equipment
Process	ESI version 4 triage manual and flowchart Workshop training and simulation-based practice Supervision, monitoring, and feedback
Outcome	Triage accuracy (primary outcome), under-triage, and over-triage Knowledge and competency of triage personnel Waiting time to see a physician and satisfaction

Figure 1 Conceptual framework

Objectives

1) To analyze the situation and causes of problems in the patient triage system of the outpatient department and emergency room of Samdet Hospital
2) To develop an ESI-based patient triage system appropriate to the context of Samdet Hospital
3) To evaluate the effectiveness of the developed system in terms of triage accuracy, knowledge, competency, triage time, and waiting time to see a physician by comparing before and after the development, and to assess staff and patient satisfaction after the development

Methods

This research and development study used a one-group pretest-posttest quasi-experimental design and was conducted in the outpatient department and emergency room of Samdet Hospital, Kalasin Province, from January

2024 to September 2025 (21 months) in four phases: Phase 1, situation analysis (January-March 2024); Phase 2, system design and development (April-June 2024); Phase 3, implementation (July 2024-March 2025); and Phase 4, evaluation and improvement (April-September 2025). Pre-development triage records were collected for April-September 2023 (retrospective data) and post-development records for April-September 2025 to control for seasonality and avoid overlap with the development period, as detailed in Figure 2.

Phase 1: Situation analysis (Jan-Mar 2024)	Review of risk reports, observation of practice, focus groups Data on the situation and causes of problems
Phase 2: System design and development (Apr-Jun 2024)	Working group, draft manual and flowchart, IOC review, 2-week pilot Content validity (IOC) assessed
Phase 3: Implementation (Jul 2024-Mar 2025)	Workshop training, full implementation, monthly supervision and monitoring Pre-training knowledge and competency assessment (Jul 2024)
Phase 4: Evaluation and improvement (Apr-Sep 2025)	Evaluation, lessons learned, improvement, and scale-up Repeat knowledge and competency assessment (Apr 2025); audit of post-development records (Apr-Sep 2025); satisfaction survey (Sep 2025)

Figure 2 The four research phases (pre-development records were retrospective data from April-September **2023)**

Population and sample

Population The population comprised 1) triage personnel of the outpatient department and emergency room of Samdet Hospital, including registered nurses, emergency medical technicians, and porters, totaling 24 persons (before the development, porters performed triage together with other staff; after the development, porters no longer performed triage but were still trained and assessed so that all participants could be compared before and after within the same group, with additional analyses by profession: registered nurses, emergency medical technicians, and porters); and 2) triage records of patients served before the development (April-September 2023, retrospective data) and after the development (April-September 2025), approximately 80,000 records per period, including approximately 79,300 from the outpatient department and 700 from the emergency room, or approximately 13,300 records per month.

Sample 1) Triage personnel: the entire population (census) of 24 persons (12 in the outpatient department and 12 in the emergency room). 2) Triage records: the sample size was calculated with G*Power for the chi-square test (df = 2) with a significance level of .05, power of 0.85, and effect size (w) of 0.12, yielding at least 759 records (w = 0.12 is a small effect by Cohen's criteria, consistent with a clinically important low-to-moderate difference in triage accuracy; N = 800 gives power = .87, and after adjusting for a design effect = 1 + (m-1)ICC with m = 16.7 records per triage person per period and ICC = 0.02

(estimated), the design effect was 1.31, the effective sample size ≈ 609 records, and power ≈ .76, which remained adequate for the effect size observed in this study (w = 0.17, power > .95)). Therefore, 800 records were used, 400 in each of the pre- and post-development periods, selected by stratified random sampling by month and department with equal allocation, 200 records per department per period (approximately 33-34 records per department per month), because the emergency room had few patients. Sampling was performed in R with seed = 2567.

Inclusion criteria Personnel: performing triage duties for at least 6 months and consenting to participate. Triage records: patients who received services through the triage point of the outpatient department or emergency room with complete records.

Exclusion criteria Personnel: continuous leave of more than 1 month, transfer, or withdrawal. Triage records: patients referred from other facilities directly to the emergency room, patients dead on arrival, and records for which the experts could not assign a standard ESI level (excluded because of incomplete records: 23 before and 14 after the development, replaced by additional random sampling to reach 400 records per period). Pediatric patients under 15 years were included in the main analysis and analyzed separately as an additional analysis.

Research instruments

The research instruments comprised 1) the development instrument, namely the ESI-based patient triage system, consisting of a triage manual and flowchart, a triage record form, role assignments, a staffing plan, and a supervision and monitoring system; and 2) data collection instruments: (1) a 20-item ESI knowledge test; (2) a triage competency assessment based on 20 simulated scenarios; (3) a triage accuracy audit form comparing assigned levels with the ESI levels determined by two experts (an emergency physician and a senior professional registered nurse in emergency nursing trained in ESI, each with at least 10 years of triage experience; the raters were blinded to the pre/post period by shuffling records and masking dates, and disagreements were adjudicated by a third expert, an emergency physician); (4) a triage time and physician waiting time record form; and (5) staff and patient satisfaction questionnaires (5-point rating scale). Content validity was examined by five experts, yielding an index of item-objective congruence (IOC) of 0.80-1.00 and a scale-level content validity index (S-CVI/Ave) of 0.95; items with IOC below 0.80 were revised before use. The reliability of the knowledge test (KR-20) was 0.82, and that of the competency assessment and satisfaction questionnaire (Cronbach's alpha) was 0.86 and 0.89, respectively. Inter-rater agreement (quadratic weighted kappa) between the two experts on 100 records was 0.85 (95% CI 0.78-0.92). KR-20 and Cronbach's alpha were tested with 30 triage personnel at a nearby community hospital who were not study participants.

Data collection

The researcher and two research assistants collected the data (the researcher was the head of the outpatient department and a supervisor and thus had a dual role toward the assessed staff; to reduce bias, the researcher did not assess accuracy or competency, assessors who were not supervisors were used, and staff completed questionnaires anonymously) as follows: 1) in Phase 1, reviewing risk reports and information system data, observing practice, and conducting

focus groups with the multidisciplinary team, patients, and relatives; 2) assessing knowledge and competency before the workshop (July 2024) and after 9 months of implementation (April 2025); 3) auditing triage accuracy and recording times from the sampled records before the development (April-September 2023, retrospective data) and after the development (April-September 2025); and 4) surveying staff and patient satisfaction in September 2025 (100 patients selected by consecutive sampling; inclusion criteria were age 18 years or older, receiving services through the triage point, ability to communicate, and consent to participate; exclusion criteria were critical illness (ESI level 1) or inability to complete the questionnaire; consent was obtained before the anonymous questionnaire).

Data analysis

Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used. Assumptions were checked with the Shapiro-Wilk test and Levene's test. Pre-post knowledge and competency scores were compared using the paired t-test, reporting mean differences with 95% CI and Hedges' g (Wilcoxon signed-rank test as a sensitivity analysis). Pre-post triage time and waiting time to see a physician were compared using Welch's t-test (Mann-Whitney U test for non-normal data). Pre-post proportions of correct triage, under-triage, and over-triage were compared using the chi-square test for each indicator, together with GEE logistic regression adjusted for triage personnel, department, and month, reporting ORs with 95% CI and Holm-adjusted p values. The primary outcome was the proportion of correct triage, with two-sided tests at $\alpha = .05$. The comparison between departments (Table 5) was not a primary objective and served as baseline information for both departments. ESI level 1-2 patients were analyzed separately with Fisher's exact test as an additional analysis. Success indicators pre-specified by the working group in Phase 2 were at least 80% of staff passing the knowledge criterion, triage accuracy of at least 70%, and satisfaction of at least 80% (mean score of at least 4.00 out of 5).

Research ethics

This study adhered to the ethical principles of human research. Before data collection, the researcher explained the objectives and procedures to the participants, who voluntarily signed informed consent. Patient names in the triage records were replaced with codes, data were kept confidential, results were presented in aggregate, and participants could withdraw at any time without any effect on their work. The ethics committee waived consent for the retrospective triage records because de-identified data were used. Patients participating in focus groups and the satisfaction survey received an explanation and gave consent before participating. To avoid pressure from the researcher as a supervisor, staff completed questionnaires anonymously without the researcher present.

Results

1. Situation analysis and causes of problems

1.1 General characteristics of the sample The 24 triage personnel comprised 14

registered nurses (58.33%), 6 emergency medical technicians (25.00%), and 4 porters (16.67%); 12 worked in the outpatient department and 12 in the emergency room. Eighteen (75.00%) were female, the mean age was 38.25 ± 7.42 years, the mean work experience was 11.50 ± 6.31 years, and 7 (29.17%) had previously received ESI triage training, as shown in Table 1.

Table 1 General characteristics of triage personnel (n = 24) by department and profession

Characteristic	Total (n = 24)	Outpatient (n = 12)	Emergency (n = 12)	Registered nurse (n = 14)	EMT (n = 6)	Porter (n = 4)
Female, n (%)	18 (75.00)	10 (83.33)	8 (66.67)	13 (92.86)	3 (50.00)	2 (50.00)
Age (years), $\bar{x}$ ± S.D.	38.25 ± 7.42	39.58 ± 7.10	36.92 ± 7.78	40.07 ± 7.05	35.17 ± 6.62	36.50 ± 8.21
Age (years), range (min-max)	26-54	27-54	26-52	28-54	26-45	27-48
Experience (years), $\bar{x}$ ± S.D.	11.50 ± 6.31	12.33 ± 6.52	10.67 ± 6.12	13.00 ± 6.40	9.50 ± 5.20	9.25 ± 6.80
Experience (years), range (min-max)	2-27	3-27	2-24	3-27	2-18	2-20
Previous ESI training, n (%)	7 (29.17)	4 (33.33)	3 (25.00)	5 (35.71)	1 (16.67)	1 (25.00)

1.2 Triage situation before the development According to Samdet Hospital information system data for 2021-2023[8] (Table 2), the proportions of over-triage were 3.13%, 3.49%, and 3.91% (p for trend = .695), and the proportions of mis-triaged urgent patients were 11.25%, 10.99%, and 12.77% (p for trend = .649), with no significant change. Under-triage in the emergency room and the outpatient department remained at 12.87-17.36% and 15.76-18.62%, respectively (no trend: p for trend = .268 and .637, respectively; Cochran-Armitage test), and some patients deteriorated in front of the outpatient examination rooms and had to be sent for urgent care in the emergency room.

Table 2 Number and percentage of triage errors, Samdet Hospital, 2021-2023

Indicator	2021	2022	2023
Under-triage, emergency room	25/144 (17.36)	20/153 (13.07)	22/171 (12.87)
Under-triage, outpatient department	23/130 (17.69)	27/145 (18.62)	26/165 (15.76)
Over-triage	5/160 (3.13)	6/172 (3.49)	7/179 (3.91)
Mis-triaged urgent patients (Urgency)	18/160 (11.25)	20/182 (10.99)	24/188 (12.77)

Note: Data are presented as number/patients triaged (%). Source: Samdet Hospital information system[8]

1.3 Analysis of the causes of problems Causes were found in three areas. 1) Service system: during 07.00-16.00, triage errors occurred in which patients of urgency level or higher were sent to wait for examination at the outpatient department, 520 of 850 patients (61.18%) (the denominator of 850 refers to patients of ESI level 3 or higher sent to wait at the wrong point in the

outpatient department during the situation analysis, January-March 2024, counted from shift incident reports; this is a process indicator, unlike Table 2, which counts annual ESI-level errors (18-24 cases per year); the night shift (00.00-08.00) was not included in the reports because night-shift patients are served directly in the emergency room), followed by the evening shift (16.00-24.00), 330 patients (38.82%). Analysis of under-triage in the emergency room showed that the most frequent error was emergent patients triaged as urgent, 19 of 35 patients (54.29%; 95% CI 38.2-69.5) (the denominator of 35 refers to patients under-triaged in the emergency room in a 2-year retrospective review of incident reports (January 2022-December 2023) after excluding 7 cases with incomplete data from 42 cases (20 + 22 cases in Table 2); the remaining 4 cases (11.43%) were under-triage at other ESI levels), followed by resuscitation patients, 12 of 35 patients (34.29%). During 07.00-08.00 and 12.00-13.00, no nurse or emergency medical technician was available, so porters performed triage instead. During 08.00-09.00, when patient volume was high, only one triage person was on duty, resulting in long waits and delayed triage. Triage staff also had to take histories and enter additional data, and supervision and monitoring were not continuous. 2) Personnel: staff had unequal triage knowledge, skills, and experience, and specific qualifications and roles had not been clearly defined. 3) Tools: triage criteria were unclear, data collection was unsystematic and discontinuous, no indicators were defined, no one was responsible for data collection, no feedback was given to staff, and triage equipment was insufficient.

2. Development of the patient triage system

2.1 The developed patient triage system

The multidisciplinary working group jointly developed a system with six components: 1) a policy and working group for developing the triage system of the outpatient and emergency departments; 2) ESI version 4 triage criteria in an easy-to-understand manual and flowchart used as a common guideline in both departments; 3) triage personnel and staffing, designating registered nurses or emergency medical technicians as triage personnel instead of porters and adding triage staff during peak hours (2 persons during 07.00-09.00); 4) capacity building of personnel in symptom assessment and triage; 5) provision of adequate triage tools and equipment; and 6) continuous supervision, monitoring of indicators, and feedback to staff. The implementation steps are shown in Table 3.

Table 3 Steps in developing and implementing the ESI-based patient triage system

Phase/month	Activities/content	Academic rationale
Phase 1 (Jan-Mar 2024)	Situation analysis; review of risk reports and information system data; observation of triage practice; focus groups with the multidisciplinary team, patients, and relatives	Systematic analysis of problems in three areas (service system, personnel, and tools) before designing solutions
Phase 2 (Apr-Jun 2024)	Working group established; roles defined; ESI triage manual, flowchart, and record form designed and drafted; expert review; pilot testing	Participation of the multidisciplinary team and use of the ESI, which is easy to use and applicable in hospitals of various levels[5]

Phase/month	Activities/content	Academic rationale
Phase 3.1 (Jul 2024)	Workshop to introduce the system, demonstration, and simulation-based triage practice, with pre-training knowledge and competency assessment	Triage personnel need preparation in knowledge and skills training and should not rely on experience alone[9]
Phase 3.2 (Aug 2024-Mar 2025)	Full implementation in both the outpatient department and the emergency room; adequate triage staffing; monthly supervision and monitoring; incident review; and feedback	Continuous monitoring of indicators and feedback allow timely improvement of practice
Phase 4 (Apr-Sep 2025)	Evaluation of knowledge, competency, triage accuracy, time, and satisfaction; lessons learned; improvement; and guidelines for scale-up	Comparison of results with success indicators to decide on continuation and scale-up

2.2 Appropriateness and feasibility of the system Five experts evaluated the congruence of the triage manual, flowchart, and record form, yielding IOC values of 0.80-1.00 (pilot tested with 8 triage personnel and 120 patients, measuring mean triage time, triage accuracy, and feasibility). The system was then piloted for 2 weeks and improved in three respects: simplifying the flowchart to shorten triage time, adding examples of presenting symptoms by disease group, and revising the record form for faster completion. The pilot showed a mean triage time of 3.40 minutes (compared with 4.82 minutes before the development), triage accuracy of 90.00% (108/120 records), and a mean feasibility score of 4.31 out of 5, supporting the appropriateness and feasibility of the system for actual use.

3. Effectiveness of the developed system

3.1 Comparison of knowledge and triage competency scores before and after the development Staff in both the outpatient department and the emergency room had significantly higher ESI knowledge and triage competency scores after the development than before ($p < .001$). Overall, among all 24 staff, the knowledge score increased from 11.41 ± 2.32 to 17.38 ± 1.71 points and the competency score from 10.88 ± 2.56 to 16.55 ± 1.96 points (difference in knowledge 5.96 points, 95% CI 4.95-6.97, and in competency 5.67 points, 95% CI 4.53-6.81; Hedges' g by department 1.90-2.36), as shown in Table 4.

Table 4 Comparison of mean knowledge and triage competency scores before and after the development by department (paired t-test)

Variable	Department	Before $\bar{x}$	Before S.D.	After $\bar{x}$	After S.D.	t	p-value
ESI knowledge (full score 20)	Outpatient	11.58	2.43	17.25	1.81	8.50	< .001*
ESI knowledge (full score 20)	Emergency	11.25	2.30	17.50	1.68	8.77	< .001*
Triage competency (full score 20)	Outpatient	10.75	2.70	16.42	2.07	7.07	< .001*

Variable	Department	Before $\bar{x}$	Before S.D.	After $\bar{x}$	After S.D.	t	p-value
Triage competency (full score 20)	Emergency	11.00	2.52	16.67	1.92	7.41	< .001*
ESI knowledge (full score 20)	Total (n = 24)	11.41	2.32	17.38	1.71	12.21	< .001*
Triage competency (full score 20)	Total (n = 24)	10.88	2.56	16.55	1.96	10.29	< .001*

Note: *Statistically significant at $p < .05$

3.2 Comparison of scores between the outpatient department and the emergency room Before and after the development, knowledge and triage competency scores did not differ significantly between the two departments ($p > .05$). However, because each department had n = 12, only large differences could be detected ($d \geq 1.2$ at power .80), so the scores of the two departments cannot be considered equal. The mean differences (outpatient - emergency) with 95% CI were 0.33 (-1.67 to 2.33) for pre-development knowledge, -0.25 (-1.73 to 1.23) for post-development knowledge, -0.25 (-2.46 to 1.96) for pre-development competency, and -0.25 (-1.94 to 1.44) for post-development competency; these confidence intervals were wide and did not exclude clinically important differences. Table 5 therefore serves only as a preliminary baseline comparison of the two departments.

Table 5 Comparison of mean knowledge and triage competency scores between the outpatient department and the emergency room (independent t-test)

Variable	Outpatient (n = 12) $\bar{x}$	Outpatient (n = 12) S.D.	Emergency (n = 12) $\bar{x}$	Emergency (n = 12) S.D.	t	p-value
Knowledge, before (full score 20)	11.58	2.43	11.25	2.30	0.34	0.736
Knowledge, after (full score 20)	17.25	1.81	17.50	1.68	-0.35	0.729
Competency, before (full score 20)	10.75	2.70	11.00	2.52	-0.23	0.817
Competency, after (full score 20)	16.42	2.07	16.67	1.92	-0.31	0.762

3.3 Triage accuracy The audit of 800 triage records showed that before the development, 82.00% were correctly triaged, 13.00% under-triaged, and 5.00% over-triaged, whereas after the development, 93.00% were correctly triaged, 4.50% under-triaged, and 2.50% over-triaged. The distribution of the three triage outcomes differed significantly ($\chi^2 = 22.61$, df = 2, $p < .001$; w = 0.17). By category, correct triage increased by 11.00 percentage points (95% CI

6.47-15.58; OR = 2.92; $\chi^2(1) = 22.13$, $p < .001$), under-triage decreased by 8.50 percentage points (95% CI 4.64-12.50; $\chi^2(1) = 18.10$, $p < .001$), and over-triage did not differ significantly (a decrease of 2.50 percentage points; $\chi^2(1) = 3.46$, $p = .063$). Holm-adjusted p values were < .001, < .001, and .063, respectively. After adjustment for triage personnel using GEE, triage accuracy remained higher after the development (adjusted OR = 2.78, 95% CI 1.41-5.48, p = .003). Among ESI level 1-2 patients only (96 records before and 104 after), under-triage decreased from 21.88% (21/96) to 8.65% (9/104) (OR = 0.34; Fisher's exact test p = .010), as shown in Table 6.

Table 6 Comparison of triage accuracy before and after the development (400 records per period) (chi-square test)

Triage accuracy	Before n (%)	After n (%)	χ^2	p-value
Correct triage	328 (82.00)	372 (93.00)	22.61	< .001*
Under-triage	52 (13.00)	18 (4.50)		
Over-triage	20 (5.00)	10 (2.50)		

Note: *Statistically significant at p < .05

3.4 Outcomes regarding time, safety, satisfaction, and success indicators After the development, the mean triage time decreased from 4.82 ± 1.95 to 2.96 ± 1.12 minutes (t = 16.54, p < .001) (difference 1.86 minutes, 95% CI 1.64-2.08; d = 1.17), and the mean waiting time to see a physician decreased from 41.37 ± 16.82 to 27.45 ± 11.36 minutes (t = 13.72, p < .001) (difference 13.92 minutes, 95% CI 11.93-15.91; d = 0.97; Welch's t-test; median (IQR) waiting time from 38.00 (28.00-52.00) to 26.00 (18.00-34.00) minutes).

Patients who deteriorated while waiting in front of the outpatient examination rooms and had to be sent for urgent care in the emergency room changed from 14 to 5 cases (1.75 and 0.63 per 10,000 records, based on a denominator of 80,000 records per period estimated from the hospital information system; exact test p = .064), and triage-related complaints changed from 5 to 1 (p = .219); these events were too few to conclude a reduction. Compared with the success indicators, 22 staff (91.67%) passed the knowledge criterion of 80.00% or higher (≥16 points), which did not differ significantly from the 80.00% target (95% CI 74.15-97.68; exact binomial test p = .115). Triage accuracy of 93.00% exceeded the 70.00% target (the success indicator was pre-specified as stated in the Methods; 95% CI for 93.00%, 90.07-95.11). The process indicator, the percentage of records triaged through all steps of the ESI flowchart, was 100% (400/400 records, 95% CI 99.05-100.00), which is a different indicator from ESI-level accuracy (93.00%).

Staff satisfaction with the system averaged 4.28 ± 0.41 (85.60%) (95% CI 4.11-4.45; compared with 4.00: t(23) = 3.35, p = .003), and patient satisfaction with the service averaged 4.38 ± 0.46 (87.60%; n = 100) (95% CI 4.29-4.47; t(99) = 8.26, p < .001; no pre-development data were available, so change cannot be interpreted; patients were selected by consecutive sampling

as stated in the Methods); both groups exceeded the criterion of 4.00 (80.00% of the full score).

Discussion

The situation analysis showed that triage errors resulted from a combination of the service system, personnel, and tools. During 07.00-09.00 and 12.00-13.00, qualified triage personnel were lacking and porters had to perform triage, and the triage criteria were broad and unclear, leading to varying judgments among triage personnel. This is consistent with studies showing that triage error rates depend on the triage personnel and the context of the facility.[12] The most common under-triage was emergent patients triaged as urgent (54.29%), resulting in long waits and deterioration. This is consistent with reports that under-triage delays diagnosis and treatment and may cause disability or death, whereas over-triage wastes resources and causes crowding.[9]

The developed system used ESI version 4 as a common guideline for both the outpatient department and the emergency room; the ESI has high validity and reliability, is easy to use, and is applicable in hospitals of various levels.[5,10,11] Development with the participation of the multidisciplinary team ensured that role assignment, staffing during peak hours, and equipment provision addressed the problems identified. In addition, workshop training combined with simulation-based practice prepared triage personnel in knowledge and skills, which is essential because accurate triage should not rely on experience alone.[9]

After the development, staff knowledge and triage competency scores increased significantly, triage accuracy increased from 82.00% to 93.00%, and under-triage decreased from 13.00% to 4.50%, consistent with the shorter waiting time to see a physician (the mean time to physician for ESI level 1 - 2 patients decreased from 9.6 to 5.1 minutes, from 10.8 to 5.7 minutes in the outpatient department and from 8.4 to 4.5 minutes in the emergency room) and with the patient safety goal of effective triage.[13] The absence of a difference between the outpatient department and the emergency room does not indicate equivalence, because n = 12 per group could detect only large differences (d ≥ 1.2) (mean differences between departments ranged from -0.25 to 0.33 points, with wide 95% CIs from -2.46 to 2.33 points, as shown in Table 5); it therefore cannot be attributed to the use of the same criteria and training. These results are consistent with ESI studies in Thailand reporting increased triage accuracy after training; Khaowong Hospital, Kalasin Province, achieved 96.80% triage accuracy after developing a model that included building staff knowledge and skills,[14] and with a meta-analysis reporting high ESI reliability, with a pooled weighted kappa of 0.79.[17]

Limitations This was a single-hospital study without a control group, so the influence of other concurrent factors, such as changes in staffing or patient volume, cannot be excluded. The accuracy raters were blinded to the pre/post period (masked dates and shuffled records) but might have inferred the period from differences in recording patterns, and the accuracy audit relied on records that might be incomplete. Other limitations were: 1) records were nested within 24 triage personnel and were therefore not independent, even after GEE adjustment; 2) each department had only 12 staff, resulting in low statistical power; 3) multiple indicators were tested, even with Holm adjustment; 4) secondary

indicators had few events (deterioration 14 to 5 cases, complaints 5 to 1); 5) no pre-development satisfaction data were available; 6) the pre- and post-development periods covered the same months in different years, which controlled for seasonality but not for secular trends; 7) ESI version 4 was used, although version 5 is now available; and 8) the researcher was a supervisor with a dual role toward staff, despite the use of other assessors and anonymous questionnaires.

Conclusion

The ESI-based patient triage system developed with the participation of a multidisciplinary team, comprising a policy and working group, triage criteria and flowchart, designation of triage personnel and staffing, staff capacity building, equipment provision, and supervision and monitoring, was associated with increased knowledge and competency, higher triage accuracy (an increase of 11.00 percentage points), reduced under-triage (8.50 percentage points), and shorter waiting time to see a physician (13.92 minutes), whereas over-triage did not differ significantly. Staff and patient satisfaction exceeded the 4.00 criterion. Given the one-group pretest-posttest design, causal effects and effects on patient safety cannot yet be concluded.

Recommendations

1. Recommendations for applying the findings 1) A lessons-learned and knowledge-sharing project should be established to create a unified, internationally recognized, up-to-date triage guideline that meets the ESI standard, using ESI version 5 of the Emergency Nurses Association (2023).[3] 2) Relevant definitions and academic literature should be reviewed, and guidelines that are easy for target groups to follow should be developed. 3) Project activities should be conducted jointly for outpatient and emergency room staff. 4) Performance should be monitored regularly to further develop a shared triage guideline between the two departments.

2. Recommendations for future research

Future studies should use a control group or multiple hospitals, follow clinical outcomes such as mortality and length of hospital stay, and examine electronic decision support systems in triage (a stepped-wedge cluster trial or interrupted time series in at least six community hospitals is proposed, with sample size calculated using ICC = 0.02 (design effect ≈ 1.31 in this study) and clinical indicators including 24-hour mortality, unplanned intensive care unit admission, and length of hospital stay).

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