
ORIGINAL ARTICLE

Development of a Surveillance System for Fungemia to Assist in Rapid Diagnosis and Treatment to Reduce the Mortality Rate in Nakhon Phanom Hospital**Supphachoke Khemla, M.D.¹, Kreingkrai Prasert, M.D., Ph.D.²**¹Division of Infectious Diseases, Department of Internal Medicine, Nakhon Phanom Hospital,²Clinical Research Center, Nakhon Phanom Hospital**Received:** December 29, 2025 **Revised:** February 6, 2026 **Accepted:** February 20, 2026

ABSTRACT

BACKGROUND: Fungemia is a severe infection associated with high mortality. Blood fungal cultures require several days to yield definitive results, leading to delays in diagnosis and treatment. Empirical antifungal therapy is therefore essential in patients with suspected fungemia before culture confirmation.

OBJECTIVES: This study compared mortality rates among patients with fungemia before and after the implementation of a surveillance system. Mortality was the primary outcome, while length of hospital stays, medical costs, and treatment complexity were the secondary outcomes.

METHODS: A retrospective cohort study was conducted among hospitalized patients with laboratory-confirmed fungemia at Nakhon Phanom Hospital between January 1, 2017, and December 31, 2024. An integrated surveillance system incorporating laboratory-based alerts, LINE notifications, and ward-based communication was implemented to streamline clinical workflows and facilitate the timely initiation of empirical antifungal therapy within 24 hours after preliminary blood culture results indicated yeast or molds.

RESULTS: A total of 108 patients were included in the analysis, comprising 74 patients in the pre-implementation control period (2017–2022) and 34 patients in the post-implementation intervention period (2023–2024). The intervention group had a significantly lower mortality rate than the control group (38.2% vs. 74.3%; $p < 0.001$). Implementation of the surveillance system was associated with a substantial reduction in mortality, with a hazard ratio of 0.26 (95% CI, 0.13–0.50), corresponding to a 74% reduction in the risk of death.

CONCLUSIONS: Implementation of an integrated surveillance system was associated with reduced mortality in patients with fungemia by enabling earlier detection and timely empirical antifungal therapy. Hospital stay lengths and costs increased, but improved survival highlighted the clinical value of this system-level intervention.

KEYWORDS: surveillance system, fungemia, empirical antifungal therapy, mortality rate

INTRODUCTION

Fungemia is a highly lethal infection, most commonly caused by *Candida* species. Its incidence, particularly among ICU patients, has recently increased with the widespread use of immunosuppressive therapies and invasive devices.¹⁻² Fungemia is associated with high mortality 35–80%, increased healthcare costs, and prolonged hospital stays.³

The global incidence of candidemia is estimated at 2–10 cases per 100,000 population per year, and varies by geographic region and patient characteristics⁴. In Thailand, the incidence is 5.1 cases per 100,000 population per year, indicating a substantial public health burden.⁵ Candidemia in Thailand has a high incidence and mortality, with more than two-thirds of the patients dying, and early detection is essential to improve outcomes.⁶

Antifungal therapy within 12–24 hours has been shown to significantly improve survival.⁷⁻⁸ In clinical practice, conventional diagnostics often delay antifungal treatment, and initiation beyond 24 hours is associated with worse outcomes and higher mortality. Rapid diagnostics and prompt clinical decision-making are therefore essential.⁹

Previous studies in Thailand have reported high mortality among patients with candidemia, with an overall mortality rate of 51.9% observed in a tertiary care hospital despite antifungal treatment.¹⁰ At Nakhon Phanom Hospital, the absence of a formal fungemia surveillance system is associated with a substantially higher mortality rate of 74.3%, largely due to delayed diagnosis and treatment. This quality improvement study evaluated the impact of an integrated fungemia surveillance system on mortality and key clinical outcomes by facilitating early detection and timely antifungal therapy.

METHODS

Study design and data collection: This retrospective cohort study included hospitalized patients diagnosed with fungemia between January 1, 2017 and December 31, 2024. The patients were categorized into two groups: a control group comprising patients treated before the surveillance system was implemented (2017 to 2022), and an intervention group comprising patients treated after its implementation (2023 to 2024) (Figure 1). An integrated surveillance system combining laboratory-based alerts, LINE notifications, and ward-based communication was implemented to streamline clinical workflows. Clinical care by attending physicians and infectious disease specialists enabled empirical antifungal therapy within 24 hours of preliminary blood culture results indicating yeasts or molds. Mortality was the primary outcome, while length of hospital stays, medical costs, and treatment complexity were the secondary outcomes. Treatment complexity was assessed using the sum of adjusted relative weights (Sum Adjusted RW) derived from the Diagnostic-Related Group (DRG) system, which reflects overall disease severity and healthcare resource utilization per admission.

Inclusion and exclusion criteria: The study included hospitalized patients aged ≥15 years with laboratory-confirmed fungemia treated at Nakhon Phanom Hospital. The Infectious Diseases Society of America (IDSA) defines fungemia as a bloodstream infection confirmed by the isolation of fungal organisms from blood cultures, while invasive fungal infection may occur without fungemia. Patients with cryptococcosis diagnosed solely by serum cryptococcal antigen testing, fungal colonization or contamination without sepsis, sepsis due to non-fungal causes, such as bacterial or viral

infections, or incomplete medical records were excluded (Figure 1).

Materials and methods: The BacT/Alert 3D automated blood culture system (bioMérieux, France) was used to detect microbial growth. Positive cultures were subcultured on blood agar, and isolated colonies were identified and tested for antimicrobial susceptibility using the BD Phoenix™ M50 system (Becton Dickinson, USA) and the ARIS (Automated Rapid Identification System). Confirmatory identification and susceptibility testing were performed at the PCT Laboratory Services (OutLab), with results interpreted in accordance with CLSI and EUCAST guidelines.

Sample size calculation: The sample size was calculated based on effect-size estimates from a pilot study at Nakhon Phanom Hospital, using a two-proportions comparison of mortality between two independent groups. The estimated pre- and post-intervention mortality rates were 74.3% and

35.0%, respectively. A two-sided significance level of $\alpha=0.05$ and 80% power were applied, yielding a required sample size of 26 patients per group (total $n=52$).

Data analysis and statistical methods: Descriptive statistics were used to summarize baseline characteristics, including frequencies, percentages, means, and standard deviations. Between-group comparisons were performed using the t-test, rank-sum test, or exact probability test, as appropriate. Length of hospital stay, medical costs, and treatment complexity were analyzed using risk differences with 95% confidence intervals, while mortality was assessed using Cox proportional hazards regression.

Ethics approval: This study was reviewed and approved by the Human Research Ethics Committee of Nakhon Phanom Hospital, Thailand (Approval No.47/2568 dated August 28, 2025 – August 27, 2026).

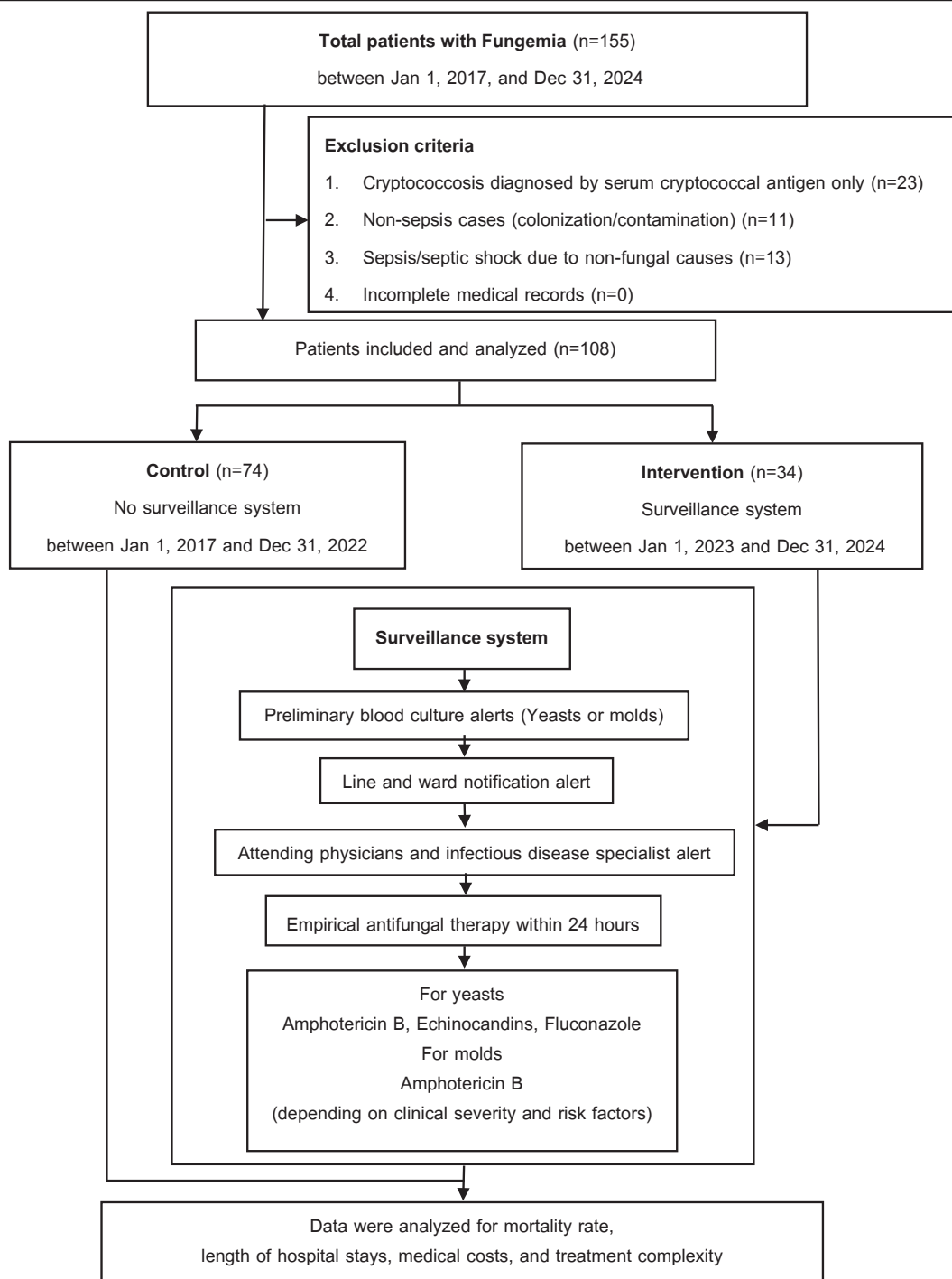


Figure 1 Flow Diagram of the Study Design and Selection Criteria

RESULTS

Table 1 Clinical Characteristics of Patients with Fungemia between the Control and Intervention Groups

Variable	Total (n=108)	Control (n=74)	Intervention (n=34)	p-value
Male, gender, n (%)	73 (67.6%)	49 (66.2%)	24 (70.6%)	0.83
Age (years), mean±SD	55±17	56±17	51±16	0.14
15-34 (years)	13 (12.0%)	8 (10.8%)	5 (14.7%)	0.67
35-59 (years)	54 (50.0%)	36 (48.7%)	18 (52.9%)	
≥60 (years)	41 (38.0%)	30 (40.5%)	11 (32.4%)	
Comorbidity, n (%)				
No underlying disease	4 (3.7%)	3 (4.1%)	1 (3.0%)	1.00
Diabetes mellitus	29 (26.9%)	20 (27.0%)	9 (26.5)	1.00
Chronic kidney disease	27 (25.0%)	19 (25.7%)	8 (23.5%)	1.00
Asthma/COPD	8 (7.4%)	5 (6.8%)	3 (8.8%)	0.71
Liver cirrhosis	9 (8.3%)	5 (6.8%)	4 (11.8%)	0.46
Malignancy	10 (9.3%)	4 (5.4%)	6 (17.7%)	0.07
HIV disease	28 (25.9%)	21 (28.4%)	7 (20.6%)	0.48
Systemic lupus erythematosus	3 (2.8%)	2 (2.7%)	1 (2.9%)	1.00
Immunosuppressant	12 (11.1%)	6 (8.1%)	6 (17.7%)	0.19
Site of infections, n (%)	105 (97.2%)	72 (97.3%)	33 (97.1%)	
Primary fungemia	3 (2.8%)	2 (2.7%)	1 (2.9%)	1.00
Respiratory tract	46 (42.6%)	32 (43.2%)	14 (41.2%)	1.00
Gastrointestinal tract	37 (34.3%)	26 (35.1%)	11 (32.4%)	0.83
Genitourinary tract	24 (22.2%)	18 (24.3%)	6 (17.7%)	0.62
Skin and soft tissue	31 (28.7%)	16 (21.6%)	15 (44.1%)	0.022
Bone and joint	10 (9.3%)	7 (9.5%)	3 (8.8%)	1.00
Central nervous system	13 (12.0%)	9 (12.2%)	4 (11.8%)	1.00
CRBSI	11 (10.2%)	9 (12.2%)	2 (5.9%)	0.50
Endocarditis	2 (1.9%)	0 (0.0%)	2 (5.9%)	0.10
Yeasts, n (%)				
<i>Candida albicans</i>	11 (10.2%)	8 (10.8%)	3 (8.8%)	1.00
<i>Candida glabrata</i>	9 (8.3%)	7 (9.5%)	2 (5.9%)	0.72
<i>Candida tropicalis</i>	18 (16.7%)	8 (10.8%)	10 (29.4%)	0.025
<i>Candida parapsilosis</i>	9 (8.3%)	6 (8.1%)	3 (8.8%)	1.00
<i>Candida krusei</i>	2 (1.9%)	1 (1.4%)	1 (2.9%)	0.53
<i>Candida zeylanoides</i>	1 (0.9%)	1 (1.4%)	0 (0.0%)	1.00
<i>Candida guilliermondii</i>	1 (0.9%)	1 (1.4%)	0 (0.0%)	1.00
Yeasts, not identified	21 (19.4%)	15 (20.3%)	6 (17.7%)	1.00
<i>Candida</i> spp.	8 (7.4%)	6 (8.1%)	2 (5.9%)	1.00
Dimorphic fungi, n (%)				
Talaromycosis	4 (3.7%)	3 (4.1%)	1 (2.9%)	1.00

Table 1 Clinical Characteristics of Patients with Fungemia between the Control and Intervention Groups (Continue)

Variable	Total (n=108)	Control (n=74)	Intervention (n=34)	p-value
Other fungi, n (%)				
<i>Cryptococcus neoformans</i>	6 (5.6%)	3 (4.1%)	3 (8.8%)	0.38
<i>Cryptococcus</i> spp.	2 (1.9%)	2 (2.7%)	0 (0.0%)	1.00
<i>Trichosporon asahii</i>	1 (0.9%)	0 (0.0%)	1 (2.9%)	0.32
Septate-hyphae, not identified	15 (13.9%)	13 (17.6%)	2 (5.9%)	0.14
Empirical treatment, n (%)				
None	55 (50.9%)	26 (35.1%)	29 (85.3%)	
Amphotericin B	53 (49.1%)	48 (64.9%)	5 (14.7%)	<0.001
Fluconazole	36 (33.3%)	16 (21.6%)	20 (58.8%)	<0.001
Fluconazole	17 (15.7%)	10 (13.5%)	7 (20.6%)	0.40
Micafungin	4 (3.7%)	1 (1.4%)	3 (8.8%)	0.09
Laboratory, mean±SD				
White blood cell, cells/μL	13,495±9,380	13,638±10,345	13,182±6,955	0.82
Neutrophils, %	82.4±13.2	84.4±9.9	77.9±17.9	0.017
Platelets, cells/μL	248,713±173,942	243,878±189,809	259,235±135,052	0.67
Blood urea nitrogen, mg/dL	41.5±35.5	45.9±35.5	32.0±34.1	0.06
Creatinine, mg/dL	2.9±3.1	3.1±3.1	2.2±2.8	0.15
Alanine transaminase, U/L	63.2±124.4	59.9±90.6	70.4±178.8	0.69
Aspartate transaminase, U/L	151.2±293.8	175.1±333.2	99.3±173.5	0.22

p-value<0.05 indicates statistical significance; Abbreviations: COPD, chronic obstructive pulmonary disease; CRBSI, catheter-related bloodstream infection; HIV, human immunodeficiency virus; spp., species; SD, standard deviation.

Baseline characteristics were comparable between groups (sex, $p=0.83$; age, $p=0.67$; comorbidities, $p=1.00$). The intervention group had higher rates of skin and soft tissue infection ($p=0.022$), *Candida tropicalis* ($p=0.025$), empirical antifungal therapy ($p<0.001$), and amphotericin B use ($p<0.001$), with similar laboratory findings except for neutrophil counts ($p=0.017$) (Table 1).

Table 2 Comparison of Mortality, Length of Hospital Stay, Medical Costs, and Treatment Complexity between the Intervention and Control Groups

Variable	Intervention (n=34)	Control (n=74)	Risk difference (95% CI)	p-value
Mortality rate, n (%)	13 (38.2%)	55 (74.3%)	0.26 * (0.13, 0.50)	<0.001
Length of hospital stay, Mean±SD (days)	26.3±27.3	15.6±13.5	-14.97 (-22.46, -7.48)	<0.001
Medical costs, Mean±SD (THB)	191,540±228,524	72,338±86,758	-119,202 (-179,350, -59,054)	<0.001
Treatment complexity, mean±SD (Sum Adj RW)	6.5±8.3	4.0±3.6	2.44 (0.18, 4.70)	0.035

*Hazard ratio using Cox's proportional hazards regression; p-value<0.05 indicates statistical significance; Abbreviations: SD, standard deviation; Sum Adj RW, the sum of adjusted relative weights; THB, Thai baht.

The intervention group showed lower mortality ($p<0.001$), costs ($p<0.001$), and treatment complexity ($p<0.001$; HR 0.26) but higher length of hospital stay ($p=0.035$) (Table 2).

Table 3 Univariable and Multivariable Cox Proportional Hazards Analysis of Factors Associated with Mortality in the Intervention Group

Factor	Univariable analysis			Multivariable analysis		
	Crude HR ^a	95% CI	p-value	Adjusted HR ^a	95% CI	p-value
Intervention group	0.26	0.13, 0.50	<0.001	0.25	0.13, 0.50	<0.001
Age groups (years)						
- 15–34	Ref.	-	-	Ref.	-	-
- 35–59	1.06	0.44, 2.53	0.90	1.39	0.53, 3.65	0.50
- ≥ 60	1.37	0.57, 3.30	0.49	1.49	0.49, 4.57	0.49
HIV disease	1.37	0.78, 2.39	0.27	1.06	0.45, 2.46	0.90
Malignancy	0.61	0.24, 1.53	0.29	1.19	0.44, 3.21	0.73
Fungal infections						
- <i>Candida albicans</i>	Ref.	-	-	Ref.	-	-
- <i>Candida non-albicans</i>	0.56	0.26, 1.19	0.13	0.60	0.26, 1.35	0.21
- <i>Candida</i> spp. (not identified)	0.61	0.19, 1.96	0.41	0.83	0.23, 2.91	0.77
- Dimorphic fungi	0.31	0.04, 2.41	0.26	0.35	0.04, 3.01	0.34
- Other*	1.31	0.63, 2.72	0.46	1.54	0.69, 3.41	0.29

^aHazard ratio using Cox's regression, *Included *Cryptococcus neoformans*, *Cryptococcus* spp. *Trichosporon asahii* and septate hyphae.

The intervention was independently associated with reduced mortality in both univariable (HR 0.26; $p<0.001$) and multivariable Cox analyses (adjusted HR 0.25; $p<0.001$), while age, HIV status, malignancy, and fungal category were not significantly associated with mortality (Table 3).

Figure 2 demonstrates higher survival in the intervention group. The Kaplan–Meier analysis showed significantly lower mortality compared with the control group (38.2% vs. 74.3%; $p<0.001$), with Cox regression confirming a 74% reduction in mortality risk associated with the intervention (HR 0.26; 95% CI 0.13–0.50).

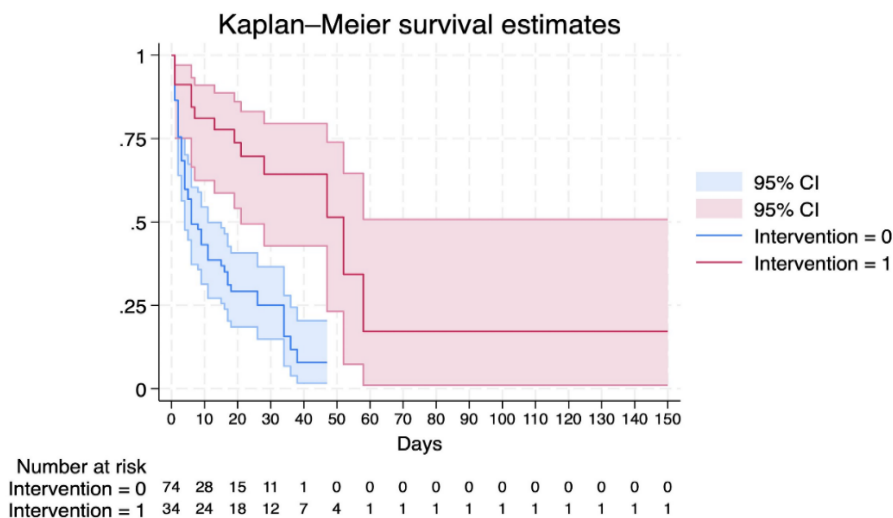


Figure 2 Kaplan–Meier Survival Curves Comparing Mortality between the Intervention and Control Groups

DISCUSSION

The implementation of an integrated surveillance system was associated with reduced mortality from fungemia despite comparable baseline characteristics. Improved survival was confirmed by Kaplan–Meier and multivariable Cox analyses, with the intervention as the only independent predictor, providing earlier detection and timely initiation of empirical antifungal therapy within 24 hours.¹⁰ These findings concurred with prior studies showing that early empirical antifungal therapy and infectious diseases consultation were associated with reduced mortality in candidemia, with reported 30-day mortality rates of 36%.¹¹ Our results demonstrated a substantial mortality reduction following the implementation of a surveillance system that facilitated early recognition of fungemia and prompt antifungal therapy.

Similarly, a previous study that evaluated an early antifungal treatment and consultation (EFTC) protocol, reported a significant reduction in 30-day mortality from 54.5% to 37.6%.¹² These findings support the effectiveness of system-based interventions that promote early recognition and timely empirical antifungal therapy in reducing mortality from candidemia and fungemia.

The intervention group experienced longer

hospital stays, higher medical costs, and greater treatment complexity, reflecting improved survival among critically ill patients.²⁻³ The higher proportion of *Candida tropicalis* and skin and soft tissue infections were not independently associated with mortality.⁹ Study limitations included the single-center design, potential residual confounding, and possible survival bias, which may limit generalizability.

A key strength of this study was the successful embedding of a pragmatic, hospital-wide surveillance system that integrated laboratory alerts and clinical communication into routine care, resulting in a meaningful reduction in fungemia-related mortality. Our findings highlight the value of system-level interventions, particularly in resource-limited settings. Future efforts should focus on scaling this model to multicenter settings, integrating rapid fungal diagnostics and antifungal stewardship, and evaluating cost-effectiveness and sustainability to optimize long-term implementation and patient outcomes.

CONFLICTS OF INTEREST: None declared

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ORIGINAL ARTICLE

การพัฒนาระบบเฝ้าระวัง (Surveillance system) ในผู้ป่วยติดเชื้อราในเลือด (Fungemia) เพื่อช่วยการวินิจฉัยและรักษาที่รวดเร็ว เพื่อลดอัตราการเสียชีวิต (Mortality rate) โรงพยาบาลนครพนมศุภโชค เข็มลา, พ.บ.¹, เกรียงไกร ประเสริฐ, พ.บ., ประด.²¹หน่วยโรคติดเชื้อ กลุ่มงานอายุรกรรม โรงพยาบาลนครพนม, ²ศูนย์วิจัยคลินิก โรงพยาบาลนครพนม**บทคัดย่อ**

ที่มาของปัญหา: การติดเชื้อราในเลือดมีความรุนแรงและอัตราการเสียชีวิตสูง การเพาะเชื้อราจากเลือดมักใช้เวลาหลายวัน ทำให้ล่าช้าในการวินิจฉัยและรักษา การให้ยาต้านเชื้อราแบบครอบคลุม เป็นกลยุทธ์สำคัญเมื่อผลเพาะเชื้อในเลือดขึ้นราเบื้องต้น แต่ยังไม่เจาะจงต่อเชื้อ การพัฒนาระบบเฝ้าระวังจะลดอัตราการเสียชีวิตลงได้

วัตถุประสงค์: เปรียบเทียบอัตราการเสียชีวิตของผู้ป่วยติดเชื้อราในเลือด ก่อนและหลังการพัฒนาระบบเฝ้าระวัง วัตถุประสงค์หลักคืออัตราการเสียชีวิต และวัตถุประสงค์รอง ได้แก่ จำนวนวันนอน ค่ารักษาพยาบาล และความซับซ้อนในการรักษา

วิธีการศึกษา: ศึกษาแบบ retrospective cohort ในผู้ป่วยโรงพยาบาลนครพนม ที่มีผลยืนยันการติดเชื้อราในเลือดระหว่าง 1 มกราคม พ.ศ. 2560 ถึง 31 ธันวาคม พ.ศ. 2567 โดยพัฒนาระบบเฝ้าระวังผ่านการแจ้งเตือนจากห้องปฏิบัติการ หอผู้ป่วย และแพทย์ เพื่อให้สามารถเริ่มยาต้านเชื้อราแบบครอบคลุมภายใน 24 ชั่วโมงหลังผลเพาะเชื้อเบื้องต้นขึ้น yeasts หรือ moulds

ผลการศึกษา: ผู้ป่วย 108 ราย แบ่งเป็นกลุ่มก่อนพัฒนาระบบเฝ้าระวัง 74 ราย (พ.ศ. 2560–2565) และกลุ่มหลังพัฒนาระบบ 34 ราย (พ.ศ. 2566–2567) กลุ่มหลังพัฒนาระบบมีอัตราการเสียชีวิตต่ำกว่าอย่างมีนัยสำคัญ (ร้อยละ 38.2 vs. ร้อยละ 74.3; $p < 0.001$) ลดอัตราการเสียชีวิต ร้อยละ 74 (hazard ratio 0.26; 95% CI 0.13–0.50)

สรุป: ระบบเฝ้าระวังมีความสัมพันธ์กับการลดอัตราการเสียชีวิตของผู้ป่วยติดเชื้อราในกระแสเลือดอย่างมีนัยสำคัญ แม้จะเพิ่มภาระด้านการรักษา แต่ผลลัพธ์ด้านการรอดชีวิตสะท้อนถึงคุณค่าเชิงคลินิกของระบบเฝ้าระวัง

คำสำคัญ: ระบบเฝ้าระวัง, การติดเชื้อราในเลือด, ยาต้านเชื้อราแบบครอบคลุม, อัตราการเสียชีวิต