

Predictive factors for invasive fungal rhinosinusitis in diabetic patients: Systematic review and data re-analysis

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Abstract

This systematic review aims to identify prognostic factors for the overall survival of invasive fungal rhinosinusitis (IFRS) in patients with diabetes using original data from the existing published articles. Systematic searches of Medline, EMBASE, and Cochrane Library databases were performed to include articles from 1988 to 2019 using the terms: “fung*” AND “rhinosinusitis” AND “invasive” AND “diabetes OR ketoacidosis”. Data from 258 diabetic patients with IFRS (mean age 55.9 years, 55.6% male, 124 studies) were extracted for data analysis. The mortality rate was 31.8%. Seven variables: plasma glucose level, HbA1C, ketoacidosis, leukopenia, serum creatinine level, duration of diabetes, and the cavernous sinus extension were assessed. Univariate analysis was done for each variable and revealed that the cavernous sinus extension was a significant risk factor. Multivariable logistic regression analysis confirmed that the cavernous sinus extension independently predicted mortality in patients with diabetes (hazard ratio (HR) 2.6, 95% confidence interval (CI) 1.2 to 5.4, $p = 0.01$). Kaplan Meier curve and Log-rank test were used for analyzing survival outcomes. The twelve-month overall survival rate of the patients with the cavernous sinus extension was 43.9% compared to 73.9% for the patients without the cavernous sinus extension ($p = 0.01$). Appropriate treatment of this condition could enhance the survival outcomes.

Key words: rhinosinusitis, diabetic ketoacidosis, cavernous sinus, glycated haemoglobin A, creatinine, blood glucose, fungal

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Introduction

Invasive fungal rhinosinusitis (IFRS) is a fatal disease with a 50-80% mortality rate and serious complications.¹ The clinical presentations of IFRS which include headache, fever, facial swelling, facial pain, and symptoms of nearby structures invasion such as ophthalmoplegia and vision problems, are similar between the two most common fungi, aspergillosis and mucormycosis. Extensive tissue necrosis, angioinvasion, extensions into the orbit, intracranial complications and the cavernous sinus extension are common complications. The incidence of IFRS in diabetic patients is increasing along with the increasing prevalence of diabetes. The WHO announced that diabetes was the seventh leading cause of death in 2016.²

Early diagnosis, prompt treatment of the IFRS and restoration of the defective immune system are essential to improve the patient's survival. The relationship between diabetes and prognosis of the IFRS is controversial. Hyperglycemia and

acidosis in diabetic ketoacidosis (DKA) result in a rapid progression of IFRS and mortality.³ However, a greater survival rate of IFRS in patients with diabetes mellitus compared to other immunosuppressive conditions was reported.⁴ The diversity of treatment outcomes across studies is due to a great variety of the immune status among the diabetic patients in the studies. Multiple factors affecting the immune system include hyperglycemic state (high plasma glucose and HbA1C levels), ketoacidosis, polymorphonuclear cell function, duration of diabetes, diabetes with multiple organ impairments. To date, prognostic factors of IFRS in diabetic patients are not evident. This systematic review aims to identify the key prognostic factors which predict the overall survival of diabetic patients with IFRS using the pooled data from the existing published articles.

Material and Methods

This systematic review followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement. Medline, EMBASE, and Cochrane database were searched using the terms: “fung*” AND “rhinosinusitis” AND “invasive” AND “diabetes OR ketoacidosis”. The last search was performed on 30 May 2019. Inclusion criteria were case reports or case series reporting IFRS patients with original data regarding diabetic condition, the disease extension, medical and surgical treatments, and survival outcomes. Data reported by the same authors or the same institutions was checked to exclude any duplication. Articles were excluded when duplication was uncertain. Case series were excluded when the data of individual patients were not separately reported. Articles in a language other than English were excluded. Diagnostic criteria for diabetes mellitus were fasting plasma glucose values ≥ 7.0 mmol/L (126 mg/dl), a 2-hour post-load plasma glucose level ≥ 11.1 mmol/L (200 mg/dl), HbA1c $\geq 6.5\%$ (48 mmol/mol); or a random plasma glucose ≥ 11.1 mmol/L (200 mg/dl) with the presence of signs and symptoms.^{5,6} Diagnostic criteria for IFRS were radiological imaging and histopathological evidence of hyphal forms within the sinus mucosa, submucosa, blood vessels, or bone.⁷

Study selection was performed independently by two reviewers (TPKN and KS). The reviewers independently screened the titles and abstracts based on the predetermined eligibility criteria. The full texts of the selected articles were reviewed. Data were extracted from the included studies using a predetermined data collection spreadsheet. Six prognostic factors related to diabetes (plasma glucose level, HbA1C, ketoacidosis, leukopenia, blood creatinine level, and duration of diabetes,) and one prognostic factor related to IFRS extension (the cavernous sinus extension) were evaluated. The outcome was overall survival. Time to event was measured from the initial diagnosis of invasive fungal sinusitis to death. Univariate analysis was done for each variable. Variables with potential risks were incorporated to multivariate analysis. Backward stepwise Cox proportional hazard model was run to assess potential hazard ratio. Kaplan Meier curve and Log-rank test were used for analyzing survival outcomes. STATA 15 was used for the data analysis. A *p*-value less than 0.05 was considered statistically significant.

Results

Study selection

A total of 1,014 articles were identified by systematic searches. There were 119 duplicates. The titles and the abstracts of 895 studies were screened, 462 full texts were reviewed, and 338 studies were excluded after the full text review. The reasons for exclusion are listed in **Figure 1**. Finally, 124 studies were included for data synthesis.⁸⁻¹³¹ A flow chart of the study retrieval and selection is presented in **Figure 1**.

Patients

There were 258 diabetic patients with IFRS. The mean age was 55.9 years and 55.6% were male. There was a wide geographical distribution. Most patients were from India (17%), followed by USA (16%), Korea (14%), Iran (9%) Turkey (8%),

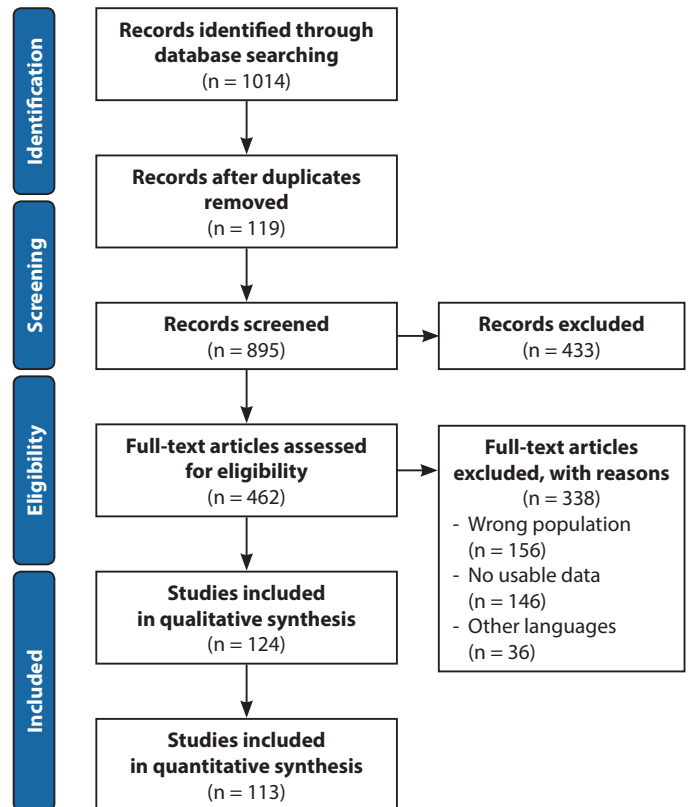


Figure 1. Prisma flow diagram on the selected manuscripts for analysis

Germany (3%), Taiwan (3%) and Japan (3%). Type II diabetes was 87.2% and type I was 12.8%. Thirteen patients (5.0%) were newly diagnosed with type II diabetes at the time of admission. Most patients (71.4%) had poor glycemic control. Fifty-one patients (19.8%) had diabetic ketoacidosis.

Mucormycosis accounted for 62.9% and aspergillosis accounted for 24.2% of the IFRS patients. Three patients (1.0%) had both mucormycosis and aspergillosis. Other types of fungi such as *Candida* species and *Absida corymbifera* accounted for 3.6%. The type of fungal hyphae was not specified in 8.6% of the patients. The mean duration of symptoms was 22.7 ± 37.6 days. Two-hundred and forty-one patients (93.4%) were diagnosed with acute IFRS and 17 patients (6.7%) were chronic IFRS. The mean duration of symptoms in acute IFRS was 12.7 ± 15 days and chronic IFRS was 103 ± 67 days. Symptoms and signs were reported in 229 patients (118 records): 152 patients (66.4%) had complaints of eye symptoms and 77 patients (33.6%) had headaches. Black eschar was the most common sign. Fourteen patients (6.1%) did not have black mucosa or necrosis. Radiological imaging was reported in 245 patients (120 records), 129 patients (52.7%) had orbital invasion and 50 patients (20.4%) had the cavernous sinus invasion. The data from 120 records showed that 221 out of the 229 patients received antifungal treatment, 89% were treated with Amphotericin B derivatives (68% received Amphotericin B derivatives as a sole agent). Among patients who received Amphotericin B derivatives, 69% of the patients improved and survived. Eight patients did not receive antifungal treatment due to renal failure, multiorgan failure and severe medical

conditions. Of the total 258 patients, 221 patients (85.6%) underwent a surgical treatment, 165 patients (63.9%) underwent endoscopic approach.

Prognostic factors and overall survival analysis

Follow-up time was reported in 207 patients (120 records). The data were used for overall survival analysis. The mortality rate was 31.8%. The mean follow-up time was 11.4 ± 18.0 months (range 0.6-120 months). Plasma glucose levels were reported in 70 patients (52 records). The mean plasma glucose level was 391.3 ± 216.4 mg/dl and 56 patients (80%) had plasma glucose above 200 mg/dl. HbA1c levels were reported in 32 patients (21 records). The mean HbA1c was 9.7 ± 2.8 and 10 patients (32%) had HbA1c greater than 11. The duration of having diabetes before admission was reported in 56 patients

(44 records). The mean duration of having diabetes was 5.6 ± 6.2 years. Nineteen patients (33%) had less than one-year duration, 21 (38%) between 1-10 years and 16 (29%) above ten years. White blood cell counts were reported in 55 patients (42 records). The mean total white blood cell count was 13,576.0 ± 8,846.5 × 10³ cell per liter. Six patients (10%) had a total white blood cell count less than 4,000 cell per liter, 18 (33%) had 4,000-11,000 and 31 (57%) had greater than 11,000. Serum creatinine was reported in 35 patients (24 records). The mean serum creatinine level was 1.5 ± 0.8 mg/dl. Twenty-eight patients (79%) had serum creatinine level greater than 1 mg/dl. Fifty-one patients (24.6%) had ketoacidosis. Radiological imaging was reported in 245 patients (120 records). Fifty patients (20%) had the cavernous sinus extension.

Table 1. Prognostic factors on overall survival of invasive fungal rhinosinusitis in diabetic patients

Risk factors	Univariate analysis				Multivariate analysis		
	Hazard ratio	95% Confidence Interval	P-value	Hazard ratio	95% Confidence Interval	p-value	
Age	1.00	0.98 - 1.01	0.86	1.00	0.98 - 1.02	0.76	
Diabetes ketoacidosis	0.68	0.39 - 1.17	0.16	1.57	0.72 - 3.43	0.26	
Cavernous sinus involvement	2.09	1.2 - 3.6	0.01	2.56	1.21 - 5.40	0.01	
Plasma Glucose	2.05	0.61 - 6.96	0.25				
HbA1C	0.38	0.05 - 3.14	0.37				
Total WBC count	1.22	0.55 - 2.72	0.62				
Creatinine	1.68	0.20 - 14.01	0.63				
Duration of DM	1.07	0.56 - 2.04	0.63				

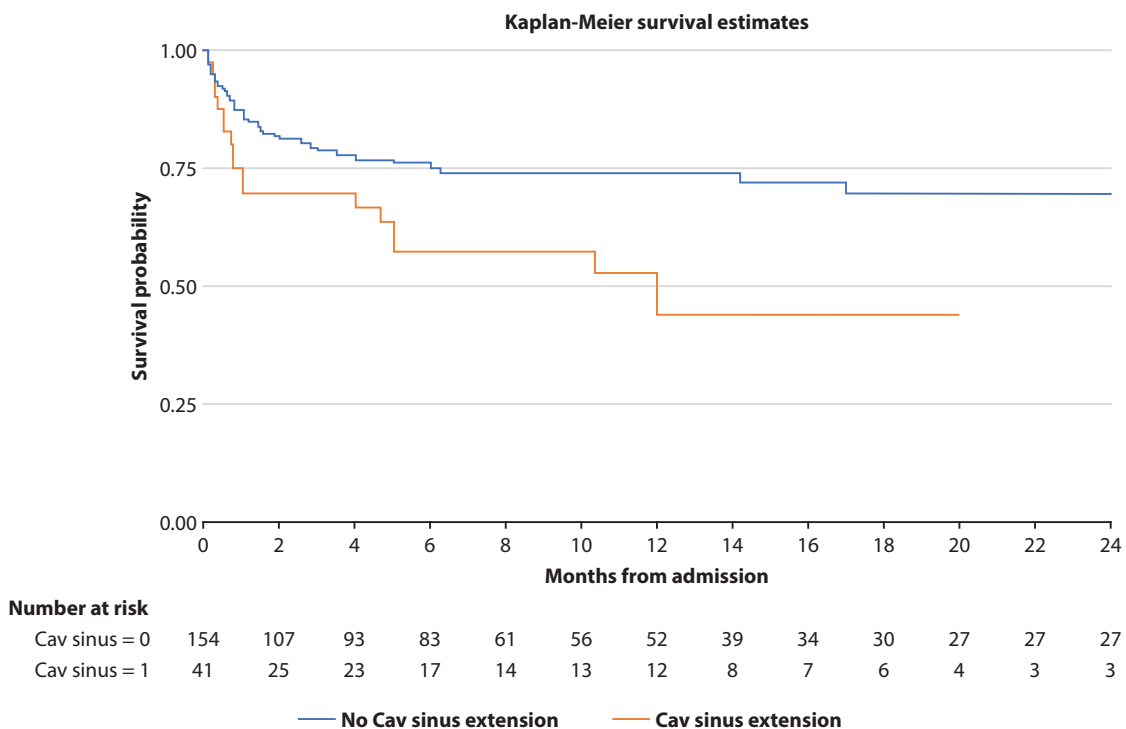


Figure 2. Overall survival of diabetic patients with invasive fungal rhinosinusitis with and without the cavernous sinus extension

The univariable logistic regression analysis revealed that the cavernous sinus extension was a significant risk factor (hazard ratio (HR) 2.1, 95% confidence interval (CI) 1.2 to 3.6, $p = 0.01$). As a potential risk factor, diabetic ketoacidosis was assessed using multivariate analysis together with the cavernous sinus extension. The multivariable logistic regression analysis showed that the cavernous sinus extension independently predicted poor prognosis (HR 2.6, 95% CI 1.2 to 5.4, $p = 0.01$). The data are displayed in **Table 1**. In the patients with the cavernous sinus extension, the overall survival at two months, six months and 12 months was 69.7%, 57.1%, and 43.9%, respectively. These overall survivals were significantly lower than those of the patients without the cavernous sinus extension (80.9%, 75.1% and 73.9%, respectively, $p = 0.01$). The data are displayed in **Figure 2**.

Discussion

In this review, the mortality rate of IFRS in diabetic patients was 31.8% which was lower than the mortality rate of IFRS in the general population (50-80 %).^{1,132,133} In line with our review, a systematic review by Turner, et al. showed that IFRS in patients with diabetes had twice the overall survival than patients with other underlying diseases.¹³³

Mucormycosis accounted for 62.9% in this systematic review. Invasive fungal rhinosinusitis in patients with diabetic ketoacidosis is mainly mucor infection rather than aspergillus infection because diabetic patients have excess iron available in the tissues and Mucors can use the excess iron to grow and spread. In addition, diabetes patients have reduced defensive cells such as neutrophils and macrophages and reduced chemotaxis and phagocytosis of the host.⁵⁶

When the raw data of individual case reports were pooled, our findings showed that the cavernous sinus extension was an independent factor which predicted the overall survival of diabetic patients with IFRS. Angioinvasion and vascular thrombosis caused by IFRS lead to the cavernous sinus extension. A basic research by Frater et al.¹³⁵ assessed histologic features of disease and the fungal morphology in 20 patients with zygomycosis. Hyphal invasion of arterial and venous walls was seen in angioinvasion (100%), and prominent infarcts (94%). Additionally, prominent perineural invasion (90%) was present in most patients. Clinical presentations of cavernous sinus extension may include bilateral exophthalmos, complete ophthalmoplegia, lid drop, and signs of meningeal irritation associated with spiking fevers.¹³⁴ Similar to the cavernous sinus thrombosis in acute bacterial rhinosinusitis, our review showed that the cavernous sinus extension by IFRS was fatal.

The cavernous sinus is a dangerous area for endoscopic sinus and skull base surgeries due to its neurovascular structures. Therefore, the cavernous sinus extension is a hard-to-treat condition.

Although other variables also have potential risks, they are correctable resulting in more favorable outcomes. Understanding immunopathology of the underlying immunocompromised diseases and restoration of the host immune dysfunction are essential for treating IFRS together with adequate

surgery and appropriate antifungal treatments. Diabetes Mellitus affects both the humoral and cellular immune responses of the innate and adaptive immune systems. The expression of class I major histocompatibility complex is impaired. The structure of complement and the balance between complement activation and restriction are altered. In poorly controlled diabetes, hyperglycemia diminishes vascular dilation and activates protein kinase C which inhibits polymorphonuclear cells production, neutrophil migration, chemotaxis and phagocytic activity.¹³⁶ Furthermore, diabetic ketoacidosis causes an overexpression of the glucose-induced glucose-regulated protein (GRP) 78 which induces endothelial cell damage and fungal invasion.¹³⁷ In addition, when acidosis is present, iron is released from its binding proteins which regulates endothelial cell damage.¹³⁸ Iron and the overexpression of glucose-induced GRP78 enhance endothelial cell susceptibility to *R. oryzae*-induced fungal invasion leading to endothelial damage.¹³⁶ Germination and rapid filamentous growth of mucormycosis within the endothelial damage, the exposed basement membrane and extracellular matrix proteins cause angioinvasion, vessel thrombosis, and necrosis.¹³⁹

IFRS is a fatal disease, therefore, neurological examination together with radiological imaging investigation should be performed to evaluate the cavernous sinus and intracranial extension. Magnetic resonance venography may be requested in specific cases for the assessment of the cavernous sinus extension. Diabetic ketoacidosis and hyperglycemic state should be assessed and treated.

The limitations of this systematic review included a retrospective nature of the included studies, and publication bias. Disadvantages of case reports and case series included missing data, confounders, and risks of bias. There were multiple factors which contributed to publication bias. Investigators commonly avoided submitting the results which were not supported by the known findings. Poor therapeutic outcomes and high mortality rate were not reported probably due to the investigators' assumption that they had made mistakes. On the other hand, publishers are not interested in the null results. In addition, most journals prefer high quality studies. Preregistered studies prior to data collection and analysis are preferred by several journals. Thus, a limited number of studies could be included.

Conclusion

Therapeutic outcomes of invasive fungal rhinosinusitis in diabetic patients are diverse. The disease extension into the cavernous sinus predicts a high mortality rate. In practice, restoration of the immune function and a total disease eradication could improve the treatment outcomes. Patients can have favorable overall survival when diabetic conditions are well controlled.

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Conflict of Interest

- Joaquim Mullol is or has been member of the advisory boards for GSK, Meda-Mylan Pharma, MSD, Novartis, SANOFI-Regeneron, AstraZeneca, and URIACH. He received Honoraria for speaking at symposia from GSK, SANOFI-Regeneron, Menarini, Meda-Mylan Pharma, MSD, URIACH, UCB, and Novartis. He received grants for research projects and clinical trials from MEDA-Mylan, SANOFI-Regeneron, GSK, Roche-Novartis, and URIACH.
- Kornkiat Snidvongs received Honoraria for speaking at symposia from Merck Sharp & Dohme, and Menarini
- Thwe Phyo Kan Nyunt has no conflict of interest.

Authors contribution

- Thwe Phyo Kan Nyunt: literature search, study selection, data collection, drafting the article, and final approval
- Joaquim Mullol: expert opinion, revising the article, and final approval
- Kornkiat Snidvongs: conception, literature search, data collection, drafting the article, and final approval

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