Acute kidney injury and the risk of mortality in patients with methanol intoxication

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Abstract

Background: Methanol poisoning is a serious public health issue in developing countries, but few data are available in the literature on acute kidney injury (AKI) after methanol intoxication.

Methods: This study examined the clinical features, spectrum and outcomes of AKI in patients with methanol intoxication and evaluated the predictors of mortality after methanol intoxication. A total of 50 patients with methanol intoxication were seen at Chang Gung Memorial Hospital between 2000 and 2013. Patients were grouped according to the status of renal damage as AKI ($n = 33$) or non-AKI ($n = 19$). Demographic, clinical, laboratory, and mortality data were obtained for analysis.

Results: Most patients were middle-aged (47.8 ± 14.9 years), predominantly male (74.0%), and habitual alcohol consumers (70.0%). Most incidents were oral exposures (96.0%) and unintentional (66.0%). Two (4.0%) patients attempted suicide by intravenous injection of methanol. Five (10.0%) patients suffered methanol intoxication after ingestion of methomyl pesticide that contained methanol as a solvent. Compared to non-AKI patients, the AKI patients were older (50.9 ± 13.7 versus 41.6 ± 15.6 years, $P = 0.034$), predominantly male (90.9% versus 42.8%, $P = 0.000$), more habitual alcohol users (84.8% versus 41.2%, $P = 0.001$) and had more unintentional exposures (82.8% versus 35.3%, $P = 0.001$). Furthermore, there was a higher incidence of respiratory failure (63.6% versus 29.4%, $P = 0.022$) in the AKI group than in the non-AKI group, respectively. The laboratory studies revealed that the AKI patients suffered from more severe metabolic acidosis than the non-AKI patients. By the end of this study, 13 (39.5%) AKI patients and 1 (5.9%) non-AKI patient had died. The overall in-hospital hospital mortality rate was 28%. In a multivariate binary logistic regression model, it was demonstrated that AKI (odds ratio 19.670, confidence interval 1.026–377.008, $P = 0.048$) and Glasgow coma scale score (odds ratio 1.370, confidence interval 1.079–1.739, $P = 0.010$) were significant factors associated with mortality. The Kaplan-Meier analysis disclosed that AKI patients suffered lower cumulative survival than non-AKI patients (log-rank test, chi-square = 5.115, $P = 0.024$).

Conclusions: AKI was common (66.0%) after methanol intoxication and was predictive of in-hospital hospital mortality. The development of AKI was associated with a 19.670-fold higher risk of in-hospital mortality.

Keywords: Methanol, Ethanol, Mortality, Acute kidney injury, Fomepizole, Haemodialysis

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Background

Methanol poisoning is a serious public health issue in developing countries [1]. Methanol is gradually metabolized via alcohol dehydrogenase to formaldehyde, which is quickly metabolized to formate, which is responsible for toxicity [2]. The clinical course of methanol toxicity is characterized by the development of metabolic acidosis after a latent period, which is the time taken for methanol to be metabolized to formate. Later, there are various visual symptoms progressing to visual impairment, but some methanol cases could develop AKI, shock, multi-organ failure or mortality [1, 2].

In this study, we investigated the clinical features, spectrum and outcomes of AKI in patients with methanol intoxication, and most importantly, we evaluated the clinical predictors of in-hospital hospital mortality after methanol intoxication.

Methods

Patients

A total of 50 patients with methanol intoxication were seen at Chang Gung Memorial Hospital between 2000 and 2013.

Inclusion and exclusion criteria

All patients aged 18 years and above were included in this study if they had a positive history of methanol exposure and their blood sample tested positive for methanol. Blood methanol level was examined by gas chromatography method [1]. Patients without identifiable blood methanol levels were excluded from this study.

Detoxification protocols

Briefly, the protocols consisted of gastric lavage with normal saline, use of sodium bicarbonate, folic acid and ethanol antidote as described previously [1]. The indications for haemodialysis were [3]: severe metabolic acidosis, visual abnormality, deteriorating vital signs, AKI, electrolyte imbalance or blood methanol level of higher than 50 mg/dL.

Haemodialysis

Haemodialysis was performed for 4 h via a temporary femoral catheter as described previously [1].

Definition of AKI

AKI was defined as an abrupt (within 24–48 h) decrease in glomerular filtration rate due to renal damage that causes fluid and metabolic waste retention and alteration of electrolyte and acid-base balance [4, 5].

Statistical analysis

The continuous variables were expressed as the means ± standard deviations for the numbers of observations, whereas the categorical variables were expressed as numbers (percentages). Non-normal distribution data were presented as medians (interquartile ranges). For comparisons between groups, Student's *t*-test was used for quantitative variables, whereas the chi-square or Fisher's exact test was used for categorical variables. Survival data were analysed with the Kaplan-Meier method and tested for significance using the log-rank test. A univariate binary logistic regression analysis was performed to compare the frequency of potential risk factors associated with mortality. The variables included acute kidney injury, age, anion gap, diabetes mellitus, ethanol level, glasgow coma scale score, habitual alcohol user, haemodialysis, hepatitis B or C virus carrier, hypertension, hypothermia, male, methanol level, osmolarity gap, pH, sodium bicarbonate, time from exposure to hospital arrival, time from exposure to haemodialysis initiation and unintentional exposure. To control for confounders, a stepwise backward multivariate binary logistic regression analysis was performed to analyse the variables that were significant on univariate analysis. The criterion for significance to reject the null hypothesis was a 95% confidence interval. The statistical analyses were performed using IBM SPSS Statistics Version 20 for Mac (IBM Corporation, Armonk, NY, USA).

Results

Table 1 shows that most of the patients were middle-aged (47.8 ± 14.9 years), predominantly male (74.0%), and habitual alcohol consumers (70.0%). The majority of the incidents were oral exposures (96.0%) and unintentional (66.0%). Two (4.0%) patients attempted suicide by intravenous injection of methanol. Furthermore, consumption of illegal commercial alcohol products accounted for most cases (56.0%) of methanol intoxication. Notably, 5 (10.0%) patients suffered methanol intoxication after ingestion of methomyl pesticide that contained methanol as a solvent.

Compared to non-AKI patients (Table 1), the AKI patients were older (50.9 ± 13.7 versus 41.6 ± 15.6 years, $P = 0.034$), predominantly male (90.9% versus 42.8%, $P = 0.000$), had higher proportions of hypertension (33.3% versus 5.9%, $P = 0.031$) and hepatitis B or C virus carriers (21.2% versus 0%, $P = 0.041$), had higher rates of unintentional exposure (82.8% versus 35.3%, $P = 0.001$), had more habitual alcohol use (84.8% versus 41.2%, $P = 0.001$) and had more consumption of illegal commercial alcohols (66.7% versus 35.5%, $P = 0.003$).

Table 2 shows that the latent periods of methanol intoxication were 5.3 ± 11.4 h and that symptoms of dyspnoea (60.0%), respiratory failure (52.0%), nausea/vomiting (42.0%), deep coma (36.0%), hypotension (32.0%), blurred vision (32.0%) and hypothermia (30.0%) were common. Moreover, there were more incidents of dyspnoea (75.8%

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Table 1 Baseline characteristics of patients with methanol intoxication, stratified according to status of renal damage as AKI or non-AKI (*n* = 50)

Variable	AKI patients (*n* = 33)	Non-AKI patients (*n* = 17)	All patients (*N* = 50)	*P* value
Age, years	50.9 ± 13.7	41.6 ± 15.6	47.8 ± 14.9	0.034*
Male, n (%)	30 (90.9)	7 (42.8)	37 (74.0)	0.000***
Hypertension, n (%)	11 (33.3)	1 (5.9)	12 (24.0)	0.031*
Diabetes mellitus, n (%)	6 (18.2)	1 (5.9)	7 (14.0)	0.235
Hepatitis B or C virus carrier, n (%)	7 (21.2)	0 (0)	7 (14.0)	0.041*
Time from exposure to hospital arrival, hours	9.6 ± 17.8	3.5 ± 5.9	7.5 ± 15.1	0.180
Time from exposure to initiation of haemodialysis, hours	22.7 ± 18.4	12.0 ± 6.5	19.0 ± 16.0	0.051
Unintentional exposure, n (%)	27 (82.8)	6 (35.3)	33 (64.0)	0.001***
Habitual alcohol user, n (%)	28 (84.8)	7 (41.2)	35 (70.0)	0.001***
Route of exposure, n (%)				0.626
Oral exposure	32 (97.0)	16 (94.1)	48 (96.0)	
Intravenous exposure	1 (3.0)	1 (5.9)	2 (4.0)	
Source of methanol, n (%)				0.003**
Illegal commercial alcohol, n (%)	22 (66.7)	6 (35.3)	28 (56.0)	
Illegal handmade alcohol, n (%)	5 (15.2)	0 (0)	5 (10.0)	
Methomyl pesticide, n (%)	3 (9.1)	2 (11.8)	5 (10.0)	
Industrial methanol, n (%)	3 (9.1)	9 (52.9)	12 (24.0)	

*P < 0.05, **P < 0.01, and ***P < 0.001

Table 2 Clinical manifestations of patients with methanol intoxication, stratified according to status of renal damage as AKI or non-AKI (*n* = 50)

Variable	AKI patients (*n* = 33)	Non-AKI patients (*n* = 17)	All patients (*N* = 50)	*P* value
Latent period, hours	6.9 ± 13.2	2.4 ± 6.0	5.3 ± 11.4	0.191
Hypothermia, n (%)	12 (36.4)	3 (17.6)	15 (30.0)	0.171
Hypotension, n (%)	13 (39.4)	3 (17.6)	16 (32.0)	0.118
Bradycardia, n (%)	5 (15.2)	2 (11.8)	7 (14.0)	0.744
Blurred vision, n (%)	11 (33.3)	5 (29.4)	16 (32.0)	0.778
Blindness, n (%)	5 (15.2)	0 (0)	5 (10.0)	0.091
Photophobia, n (%)	1 (3.0)	1 (5.9)	2 (4.0)	0.626
Mydriasis, n (%)	5 (15.2)	1 (5.9)	6 (12.0)	0.339
Dyspnoea, n (%)	25 (75.8)	5 (29.4)	30 (60.0)	0.002**
Acute respiratory failure, n (%)	21 (63.6)	5 (29.4)	26 (52.0)	0.022*
Nausea/vomiting, n (%)	14 (42.4)	7 (41.2)	21 (42.0)	0.933
Gastrointestinal bleeding, n (%)	12 (36.4)	4 (23.5)	16 (32.0)	0.357
Abdominal pain, n (%)	10 (30.3)	3 (17.6)	13 (26.0)	0.334
Pancreatitis, n (%)	4 (12.1)	0 (0)	4 (8.0)	0.134
Hepatitis, n (%)	2 (6.1)	0 (0)	2 (4.0)	0.300
Glasgow coma scale score	9.5 ± 5.5	11.8 ± 5.2	10.3 ± 5.5	0.170
Deep coma, n (%)	14 (42.4)	4 (23.5)	18 (36.0)	0.187

*P < 0.05 and **P < 0.01

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versus 29.4%, *P* = 0.002) and respiratory failure (63.6% versus 29.4%, *P* = 0.022) in the AKI patients than in the non-AKI patients. In addition, the laboratory studies found that AKI patients suffered from more severe metabolic acidosis than non-AKI patients (Table 3). Nevertheless, none of the patients suffered from haemolysis or myoglobinuria.

By the end of this study, 13 (39.5%) AKI patients and 1 (5.9%) non-AKI patient had died. The overall in-hospital hospital mortality rate was 28% (Table 4).

In a multivariate binary logistic regression model (Table 5), it was demonstrated that AKI (odds ratio 19.670, confidence interval 1.026–377.008, *P* = 0.048) and Glasgow coma scale score (odds ratio 1.370, confidence interval 1.079–1.739, *P* = 0.010) were significant factors associated with mortality. The presence of AKI was associated with a 19.670-fold higher risk of in-hospital mortality. Finally, the Kaplan-Meier analysis

disclosed that AKI patients suffered lower cumulative survival than did non-AKI patients (Fig. 1) (log-rank test, chi-square = 5.115, *P* = 0.024).

Discussion

The overall in-hospital mortality rate was 28.0, and 66.0% of these patients suffered from AKI. These figures were comparable with data from other poison centres. As shown in Table 6, the published AKI and mortality rates were 15.4–66.0% and 0–48.0%, respectively [1, 6–25]. Therefore, patients with AKI should be recognized early and aggressively treated to avoid severe complications or mortality.

AKI is a life-threatening complication that is associated with high death rates in intoxicated patients. The main aetiologies of AKI are ischaemia, hypoxia, or nephrotoxicity [26]. In cases of methanol intoxication,

Table 3 Laboratory data at admission of patients with methanol intoxication, stratified according to status of renal damage as AKI or non-AKI (*N* = 50)

Variable	AKI patients (*n* = 33)	Non-AKI patients (*n* = 17)	All patients (*N* = 50)	*P* value
Blood urea nitrogen, mg/dL	22.4 ± 18.1	12.4 ± 4.3	18.8 ± 15.4	0.035*
Creatinine, mg/dL (admission)	2.51 ± 1.24	0.87 ± 0.17	1.97 ± 1.28	0.000***
Creatinine, mg/dL (peak)	3.23 ± 2.00	1.12 ± 0.94	2.54 ± 1.99	0.000***
Methanol level, mg/dL	33.1 ± 77.2	64.5 ± 75.5	43.8 ± 77.4	0.176
Ethanol level, mg/dL	48.6 ± 57.0	71.6 ± 125.3	56.4 ± 85.8	0.390
Arterial blood gas				
pH	7.055 ± 0.232	7.306 ± 0.190	7.141 ± 0.248	0.000***
pCO_2, mmHg	26.5 ± 14.1	36.9 ± 11.1	30.0 ± 13.9	0.011*
pO_2, mmHg	110.3 ± 60.0	112.8 ± 58.7	111.2 ± 59.0	0.890
Bicarbonate, mmol/L	8.7 ± 7.3	18.8 ± 6.8	12.2 ± 8.6	0.000***
Base excess, mmol/L	−17.9 ± 10.0	−7.4 ± 9.1	−13.5 ± 10.9	0.001**
Osmolarity, mOsm/kg H_2O	341.0 ± 42.1	329.3 ± 26.0	336.9 ± 37.4	0.351
Osmolarity gap, mOsm/kg H_2O	50.5 ± 84.2	37.3 ± 28.4	44.7 ± 65.0	0.624
Anion gap, mmol/L	33.4 ± 14.8	16.3 ± 7.3	27.2 ± 15.0	0.000***
Calcium, mEq/L	7.7 ± 0.9	7.5 ± 0.9	7.7 ± 0.9	0.526
Sodium, mEq/L	138.1 ± 6.1	141.7 ± 3.1	139.3 ± 5.5	0.029*
Potassium, mEq/L	4.6 ± 1.1	3.5 ± 0.6	4.2 ± 1.1	0.001*
Chloride, mEq/L	96.8 ± 8.9	106.9 ± 3.5	100.6 ± 8.8	0.000***
Amylase, mg/dL	137.8 ± 84.0	294.3 ± 477.4	182.5 ± 250.7	0.310
Lipase, mg/dL	179.1 ± 206.4	39.5 ± 14.0	154.8 ± 194.4	0.199
Albumin, g/dL	3.05 ± 1.01	3.57 ± 0.69	3.26 ± 0.91	0.297
Aspartate aminotransferase, U/L	303.7 ± 507.1	50.3 ± 37.9	245.2 ± 455.6	0.240
Alanine aminotransferase, U/L	96.4 ± 122.1	32.0 ± 24.7	73.9 ± 103.6	0.060
Random glucose, mg/dL	223.6 ± 145.5	126.6 ± 34.1	183.0 ± 121.8	0.026*
White blood cell count, 1000/μL	16.2 ± 9.7	11.6 ± 6.1	14.6 ± 8.8	0.077
Haemoglobin, g/dL	13.2 ± 3.1	14.0 ± 1.6	13.5 ± 2.7	0.311
Platelet count, 1000/μL	192.2 ± 109.6	242.9 ± 68.4	209.4 ± 99.8	0.089

*P < 0.05, **P < 0.01, and ***P < 0.001

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Table 4 Outcome of patients with methanol intoxication, stratified according to status of renal damage as AKI or non-AKI (n = 50)

Variable	AKI patients (n = 33)	Non-AKI patients (n = 17)	All patients (N = 50)	P value
Gastric lavage, n (%)	22 (66.7)	7 (41.2)	29 (58.0)	0.084
Endotracheal intubation, n (%)	21 (63.6)	5 (29.4)	26 (52.0)	0.022*
Inotropic agent infusion, n (%)	13 (39.4)	3 (17.6)	16 (32.0)	0.118
Sodium bicarbonate, n (%)	27 (81.8)	7 (41.2)	34 (68.0)	0.004**
Ethanol, n (%)	13 (39.4)	8 (47.1)	21 (42.0)	0.603
Fomepizole, n (%)	0 (0)	0 (0)	0 (0)	1.000
Folic acid, n (%)	18 (54.5)	8 (47.1)	26 (52.0)	0.616
Haemodialysis, n (%)	24 (72.7)	13 (76.5)	37 (74.0)	0.775
Duration of hospitalization, day	9.5 ± 9.1	8.8 ± 8.0	9.2 ± 8.7	0.785
In-hospital mortality, n (%)	13 (39.4)	1 (5.9)	14 (28.0)	0.012*

*P < 0.05 and **P < 0.01

AKI has been reported, but limited studies have been performed to study this renal outcome. Although Salek et al. [20] found that only 2 of 13 (15.4%) methanol patients developed AKI, our previous analysis [1] indicated that AKI is common (19 of 32 or 59.4%) after methanol exposure. Similarly, Verhelst et al. [8] found that AKI developed in 15 of 25 (60.0%) patients with methanol intoxication. Compared 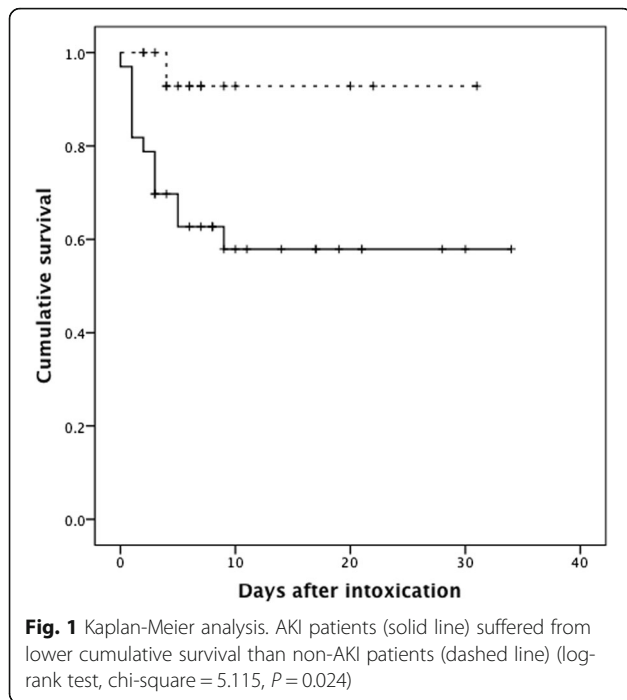with 10 non-AKI patients, the 15 AKI patients had a lower blood pH value on admission, a higher serum osmolality, and a higher peak formate concentration. According to Verhelst's study [8], the aetiologies of methanol nephrotoxicity may be due to direct factors, such as high blood methanol and formate concentrations, or indirect factors, such as haemolysis and myoglobinuria [8].

Nevertheless, the aetiologies of AKI in our patients remained uncertain. In contrast to Verhelst's hypothesis,

Table 5 A binary logistic regression model for analysis of mortality (N = 50)

Variable	Univariate analysis Odds ratio (95% confidence interval)	P value	Multivariate analysis Odds ratio (95% confidence interval)	P value
Acute kidney injury (yes)	10.400 (1.227–88.178)	0.032*	19.670 (1.026–377.008)	0.048*
Age (each increase of 1 year)	1.044 (0.997–1.093)	0.070		
Anion gap (each increase of 1 mmol/L)	1.025 (0.980–1.072)	0.275		
Diabetes mellitus (yes)	1.033 (0.176–6.067)	0.971		
Ethanol level (each increase of 1 mg/dL)	0.996 (0.989–1.004)	0.324		
Glasgow coma scale score (each decrease of 1 score)	1.420 (1.171–1.721)	0.000***	1.370 (1.079–1.739)	0.010*
Habitual alcohol user (yes)	1.833 (0.429–7.836)	0.413		
Haemodialysis (yes)	0.833 (0.209–3.323)	0.796		
Hepatitis B or C virus carrier (yes)	2.182 (0.421–11.318)	0.353		
Hypertension (yes)	2.302 (0.585–9.056)	0.233		
Hypothermia (yes)	15.500 (3.474–69.159)	0.000***	6.905 (0.724–65.873)	0.093
Male (yes)	2.640 (0.504–13.835)	0.251		
Methanol level (each increase of 1 mg/dL)	1.003 (0.993–1.012)	0.598		
Osmolarity gap (each increase of 1 mOsm/kg H_2O)	1.016 (0.997–1.036)	0.101		
pH (each decrease of 1 unit)	59.981 (3.074–878.999)	0.006**	3.981 (0.061–258.848)	0.517
Sodium bicarbonate (yes)	0.262 (0.051–1.350)	0.109		
Time from exposure to hospital arrival (each increase of 1 h)	1.034 (0.970–1.101)	0.306		
Time from exposure to haemodialysis initiation (each increase of 1 h)	1.001 (0.956–1.049)	0.954		
Unintentional exposure (yes)	1.413 (0.368–5.419)	0.614		

*P < 0.05, **P < 0.01, and ***P < 0.001

Fig. 1 Kaplan-Meier analysis. AKI patients (solid line) suffered from lower cumulative survival than non-AKI patients (dashed line) (log-rank test, chi-square = 5.115, $P = 0.024$)

none of the patients suffered from haemolysis or myoglobinuria. There were more incidents of respiratory failure ($P = 0.022$) in the AKI group than in the non-AKI group. These patients were intubated and receiving mechanical ventilator support. Previous studies [27, 28] have demonstrated that AKI can be induced by acute lung injury, which occurs because lung damage releases inflammatory mediators into the bloodstream that can affect renal function. According to a meta-analysis study [29], endotracheal intubation is associated with a three-fold increase in the odds of developing AKI. Compared to non-AKI patients, the AKI patients were also older ($P = 0.034$) and had higher proportions of hypertension ($P = 0.031$). The association between age and hypertension is not surprising. As pointed out previously [30], many clinical circumstances could predispose a patient to progress with AKI, including age, sepsis, operation, and co-morbidities, such as hypertension, diabetes mellitus, cardiovascular disease, malignancy, and chronic kidney disease.

The analysis indicates that AKI was associated with a higher risk of in-hospital death. In a multivariate binary logistic regression model, it was demonstrated that AKI was a significant factor associated with mortality ($P = 0.048$, Table 5). Kaplan-Meier analysis also revealed AKI patients suffered lower cumulative survival than non-AKI patients

Table 6 Comparison of AKI and mortality rates between current and published studies (sample size ≥10)

Study	Year	Area	Sample size, n	Methanol level, mg/dL	AKI rate, %	Mortality rate, %
Liu et al. [6]	1998	Canada	50			36.0
Meyer et al. [7]	2000	America	24			33.3
Verhelst et al. [8]	2004	Belgium	25		60.0	24.0
Hovda et al. [9]	2005	Norway	51	80.0		17.6
Hassanian-Moghaddam et al. [10]	2007	Iran	25			48.0
Paasma et al. [11]	2007	Estonia	154			44.0
Brahmi et al. [12]	2007	Tunisia	16	140.0		19.0
Rzepecki et al. [13]	2012	Polish	288	50.1		3.8
Paasma et al. [14]	2012	Norway, Estonia, Tunisia, Iran	203	140.6		23.6
Shah et al. [15]	2012	India	63			31.7
Kute et al. [16]	2012	India	91			3.3
Massoumi et al. [17]	2012	Iran	51			7.8
Desai et al. [18]	2013	India	122	15.9		8.2
Sanaei-Zadeh et al. [19]	2013	Iran	42			40.5
Salek et al. [20]	2014	Czech	13	143.0	15.4	0
Zakharov et al. [21]	2014	Czech	121	86.9		33.9
Lee et al. [1]	2014	Taiwan	32	121.9	59.4	34.4
Lachance et al. [22]	2015	Canada	55	200.0		1.8
Rostrup et al. [23]	2016	Libya; Kenya	1066; 467			9.5; 26.9
Collister et al. [24]	2017	Canada	10	23.5		
Rulisek et al. [25]	2017	Czech	106	27.8		21.7
Current study	2018	Taiwan	50	43.8	66.0	28.0

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(P = 0.024) (Fig. 1). Clinical evidence suggests that AKI not only is an indicator for severity of illness but also leads to earlier onset of multi-organ dysfunction with profound effects on mortality rates [31]. In laboratory studies, it is demonstrated that AKI is not an isolated event; it engenders remote organ injury through a series of events that involves pro-inflammatory cytokine release, oxidative stress, immune cell stimulation, leukocyte extravasation, endothelial cell damage and vessel permeability leading to tissue oedema development [31, 32]. Our previous studies also revealed that AKI predicts mortality after intoxications, such as paraquat [5] or charcoal burning [33] suicide.

The foundation of treatment for methanol intoxication is the administration of an antidote, which blocks the function of alcohol dehydrogenase, thereby preventing the formation of toxic metabolites [34]. There are two antidotes: ethanol (a competitive alcohol dehydrogenase substrate) and fomepizole (an alcohol dehydrogenase inhibitor), which can be administered to block alcohol dehydrogenase metabolism. Nevertheless, none of our patients received fomepizole therapy because this drug was not available at our hospital (Table 4).

Five (10.0%) patients suffered methanol intoxication after ingestion of methomyl pesticide that contained methanol as a solvent (Table 1). The clinical findings observed in these cases were similar to a previous outbreak of foodborne illness due to methomyl pesticide intoxication in Korea [35]. It is possible that the combined toxicity of methomyl pesticide and methanol solvent was responsible for the symptoms. Methomyl pesticide is exceptionally toxic if ingested [36]. It is a carbamate insecticide and can induce acute cholinergic crisis by reversible inhibition of cholinesterase [37]. To minimize health impacts, the United States Environmental Protection Agency has classified methomyl products used in agricultural settings as "restricted use", meaning that they can be used only by or under the supervision of certified farmers [36].

Two (4.0%) patients attempted suicide by intravenous injection of methanol (Table 1). Their blood methanol concentrations were 71.2 mg/dL and 5.0 mg/dL. Both patients were successfully treated with haemodialysis without any complications. Few human data exist in the literature regarding the outcome of intravenous methanol poisoning, although the methanol extraction residue of Bacillus Calmette-Guerin could be safely injected into patients with advanced cancer by the intravenous route without causing complications [38]. Nevertheless, the administered amount was very low under that circumstance. Wang et al. [39] reported a human case of intravenous methanol intoxication in 1997. Ophthalmologic examination on the seventh day disclosed hyperaemia of the optic disc with peripapillary haemorrhage and cotton-wool spots. The severity of retina injury was caused by 100% bioavailability of methanol after intravenous injection and lack of first-pass metabolism [39]. In addition, the patient arrived at the hospital too late (after 7 days) to take advantage of detoxification procedures. On the other hand, the good prognosis of the current 2 patients depends on early hospital arrival, prompt diagnosis of methanol intoxication and speedy initiation of haemodialysis.

Conclusions

AKI was common (66.0%) after methanol intoxication and was predictive of in-hospital mortality. The development of AKI was associated with a 19.670-fold higher risk of in-hospital mortality. Therefore, patients with AKI should be recognized early and aggressively treated to avoid mortality. Nevertheless, the retrospective nature of the study, small sample size, short follow-up duration, and absence of pre-admission serum creatinine and urine output measurements limit the certainty of our conclusions.

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