Anaesth Intensive Care 2009; 37: 968-975

Incidence of contrast-induced nephropathy in intensive care patients undergoing computerised tomography and prevalence of risk factors

A. H. RASHID*, J. L. BRIEVA†, B. STOKES‡

Intensive Care Unit, John Hunter and Calvary Mater Hospital, Hunter New England Area Health, Newcastle, New South Wales, Australia

SUMMARY

Computerised tomography (CT) with contrast is frequently used in intensive care. Contrast-induced nephropathy (CIN) is an important complication largely studied in stable cardiology patients and can lead to acute renal failure. The aim of this study was to determine the incidence of CIN in an intensive care unit (ICU) setting and describe the prevalence of associated risk factors. We performed a retrospective analysis by review of electronic laboratory database and manual chart review of all patients in two tertiary intensive care units in Newcastle, New South Wales who underwent CT with intravenous contrast during their ICU stay in 2006. CIN was defined as an absolute increment in serum creatinine of 44.2 μmol/l or a relative increment of 25% from baseline at 48 to 72 hours following intravenous contrast. Patients' demographic, biochemical and contrast media data, physiological parameters, fluid and drug administrations and previously described as well as ICU specific risk factors were analysed. We compared CIN positive and CIN negative patients to identify risk factors associated with CIN. In total, 2043 patients were admitted to ICU during 2006 and 509 CT studies were performed. One hundred and forty-one of these included administration of intravenous contrast and 139 charts were reviewed. Sixteen out of 139 patients developed CIN (11.5%). More than 70% of patients had two or more risk factors. Age was the only risk factor found to be significantly associated with the development of CIN in a multivariate analysis (P value 0.04, OR 1.041, 95% confidence interval 1.002 to 1.081). Mortality was higher in CIN positive patients (31 vs 13%, P value 0.068). ICU and hospital length of stay was not significantly different in CIN positive and negative patients and persisting renal impairment was not found in CIN positive survivors. Based on this study, we cannot predict who will develop CIN in ICU using the described risk factors. Further prospective studies are needed to evaluate the incidence and outcomes of CIN in an ICU setting.

Key Words: nephropathy, contrast-induced, intensive care, incidence, risk factors

Computerised tomography (CT) is a frequently used investigation for hospitalised patients, including those in intensive care. The intravascular contrast media (CM) commonly administered during these examinations is a well recognised cause of acute renal dysfunction, known as contrast-induced nephropathy (CIN)[1]. Although CIN is usually transient, permanent renal injury has been reported in around 30%[2-4]. Iodinated radio-contrast is the third most common cause of hospital-acquired acute renal failure, responsible for around 11% of cases[2-4].

Acute renal failure in critically ill patients is an important problem associated with increased hospital resource use and increased morbidity and mortality[5,6]. A mortality of 64% at one year was reported recently in adult intensive care unit (ICU) patients requiring renal replacement therapy[6].

CIN has been studied largely in stable cardiology patients receiving contrast during percutaneous coronary intervention[7-9]. It remains controversial whether risk factors for CIN described in these settings can be extrapolated to the ICU population. The incidence of CIN reported in the literature varies from 5 to 50% depending on the definition used, type of CM and the age of the study[9]. The incidence of CIN in ICU patients remains uncertain and there are no published data for Australian ICUs.

* M.B., B.S., B.Sc., F.J.F.I.C.M., Intensive Care Fellow.
† F.J.F.I.C.M., Intensive Care Specialist.
‡ Ph.D., Research Academic, Discipline of Clinical Pharmacology, School of Medicine and Public Health Faculty of Health, University of Newcastle.

Address for correspondence: Dr A. H. Rashid, 64 Lookout Rd, New Lambton Heights, NSW 2305.

Accepted for publication on April 30, 2009.

The aim of this study is two-fold: 1) to determine the incidence of CIN in an Australian ICU setting and 2) to describe the prevalence of risk factors that might be used to predict susceptibility to CIN in ICU.

METHODS

We performed a retrospective chart and medical notes review of all patients in two ICUs in the Hunter region who underwent CT with intravenous contrast during their ICU stay in the study period of 2006. The CM given was Ultravist 300. John Hunter hospital has a 14-bed mixed adult and paediatric level III ICU. Calvary Mater has a six-bed mixed ICU.

Study patients were identified within the local radiology database indicating the date and type of contrast CT scan performed. Where patients were exposed to multiple CT scans during ICU or hospital admission, this was noted but data was extracted pertaining only to the first scan in ICU to minimise potential bias.

A case report form was designed to record physiological variables and risk factors for each patient. Data was transferred into an electronic database.

Definition of CIN

We defined CIN as an absolute increment in serum creatinine of 44.2 μmol/l or a relative increment of 25% from baseline at 48 to 72 hours following contrast CT[2]. This incorporates the definition of the European Society of Urogenital Radiology[3,4] and the original definition of Barrett and Parfrey[1].

Biochemical data was accessed from the electronic laboratory results system. Fluid balance, haemodynamic and oxygenation variables at baseline and following CT were obtained by chart review. Baseline and 12 to 72 hours values were recorded. Patients' admission Acute Physiology and Chronic Health Evaluation (APACHE) II scores and diagnoses were drawn from the ICU database. We also noted the presence of sepsis at the time of CT, defined as per the Society of Critical Care Medicine Consensus[5]. Any specific preventive measures undertaken to avoid CIN, such as administration of fluid boluses or acetylcysteine, were also recorded. Volumes, route of administration and type of CM given during CT were analysed.

Risk factor selection and identification

We reviewed the available CIN literature to identify previously described risk factors. These 'conventional' risk factors comprised: documented history of pre-existing hypertension, diabetes (type 1 or 2), renal impairment, concurrent administration of diuretics and nephrotoxic medications, age >75 years, contrast volume >1 ml/kg, intra-arterial injection and multiple studies. In an attempt to identify ICU specific risk factors, we collected data on fluid balance, haemodynamic and oxygenation variables at baseline and post CT. These variables have not been described previously in non-ICU settings and provided information regarding patients' volume status, haemodynamic stability and oxygen delivery peri-CT.

Outcomes

The main outcome was incidence of CIN and risk factor identification. Secondary outcomes were ICU and hospital length of stay, ICU and hospital mortality and requirement for renal replacement therapy.

A submission to the area health service research and clinical ethics committee was made. The study was authorised and a formal informed consent waived.

Statistical analysis

To evaluate the possible association between a risk factor and CIN, all categorical independent variables with more than two values were analysed with Fisher's exact and chi-square test. The t-test was used to analyse all continuous independent variables. A P value of less than 0.05 was considered statistically significant. Binary logistic regression analysis (odds ratio [OR], 95% confidence interval [CI]) was used to test for any significant association between CIN and risk factors. Decision tree and linear discriminant analysis were performed with SAS v6 and Mathematica v9 for Windows to test for risk factor and CIN association.

RESULTS

During the 2006 study period, a total of 2043 patients were admitted to the intensive care units and 509 CT studies (contrast and non-contrast) were performed. We identified 141 patients who received contrast for CT and located and examined the charts of 139 of these patients (Figure 1). The patients' baseline characteristics are shown in Table 1. A total of 16 out of 139 patients developed CIN, giving an incidence of CIN of 11.5% (95% CI 6.2 to 16.8).

The risk factors for CIN commonly described in the literature in non-ICU studies were often present in this ICU population (Figure 2). Multiple risk factors were identified in the majority of ICU patients. More than 70% of patients had two or

TABLE 1
Baseline characteristics. Mean ± standard deviation (SD) for non-discrete data and percentages/ranges of data.

	mean ± SD	%/(range)
Gender		
Male	85	61.10%
Female	54	38.90%
Age	57±19.2	(3-87)
Body mass index	27.0±6.9	(13.7-53)
APACHE II	19.8±8.7	(4-52)
Admission diagnosis		
Surgical	77	55.30%
Medical	62	44.70%
Haemodynamics		
24 h fluid balance (ml)*	1513±2309	(-4050-12000)
Vasopressors (μg/kg/min)	0.03±0.16	(0-0.14)
Inotropes (μg/kg/min)	0.19±1.1	(0-6.5)
MAP (mmHg)#	82.6±15.7	(20-140)
CVP (mmHg)#	11.2±4.9	(3-24)
Urinary output (ml/kg/h)**	1.3±1.4	(0-11.7)
Pre-study Rx		
Fluid bolus (ml)	104.3±430.9	(0-4000)
Acetylcysteine	1	0.80%
Oxygenation#		
FiO_2	0.41±0.14	(0.21-1.0)
S_aO_2	96.9±2.2	(90-100)
PEEP (cmH_2O)	4.4±3.5	(0-15)
Laboratory#		
Haemoglobin (g/l)	104.1±21.3	(68-170)
Creatinine (μmol/l)	115.3±112.3	(19-730)
Contrast dose		
>1 ml/kg	85	61.10%
<1 ml/kg	54	38.90%
Total volume (ml)	86.3±27.6	(40-300)
Renal impairment		
yes##	27	19.40%
no	112	80.60%
Hypertension		
yes	48	34.50%
no	91	65.50%
Diabetes mellitus		
yes	19	13.60%
no	120	86.40%
Diuretic therapy		
yes	17	12.20%
no	122	87.80%
Nephrotoxic medications		
yes###	31	22.30%
no	108	77.70%
Arterial contrast		
yes	4	2.80%
no	135	97.20%
Multiple studies		
yes	58	41.70%
no	81	58.30%
CIN		
yes	16	11.50%
no	123	88.50%
Renal replacement therapy		
yes	10	7.10%
no	129	92.90%
Age >75 y		
yes	23	16.50%
no	116	83.50%
Sepsis		
yes	39	28.00%
no	100	72.00%
Length of stay (days)		
ICU	10.1±9.7	(1-50)
Hospital	34.3±41.7	(1-262)
ICU mortality	21/139	15.10%
Hospital mortality	40/139	28.70%

APACHE II=Acute Physiology and Chronic Health Evaluation II score, MAP=mean arterial pressure, CVP=central venous pressure, PEEP=positive end-expiratory pressure, CIN=contrast-induced nephropathy, ICU=intensive care unit. * 24 hour fluid balance on the day of contrast CT, # baseline measurement at/closest to time of CT, ** urine outputs averaged over six hours, ## renal impairment-creatinine at baseline 1.5×normal or urine output 0.5 ml/kg/h for six hours (pre-contrast administration). ### nephrotoxics considered included non-steroidals, aminoglycosides, cyclosporin, amphoteracin and ACE inhibitors.

more risk factors. A large proportion of risk factors constitute 'non-modifiable' patient related factors, such as age >75 years (16.5%), sepsis (28%) and pre-existing conditions such as diabetes mellitus (13.6%), renal impairment (19%) and hypertension (34.5%). However, an important number of 'modifiable' or procedure related factors were also found, such as dose of CM >1 ml/kg (61%) and multiple studies (41%) (Figure 3).

Comparison of these risk factors in CIN positive and negative patients showed no statistically significant difference in conventional risk factors between these two groups. When examining ICU specific risk factors, CVP at baseline was statistically

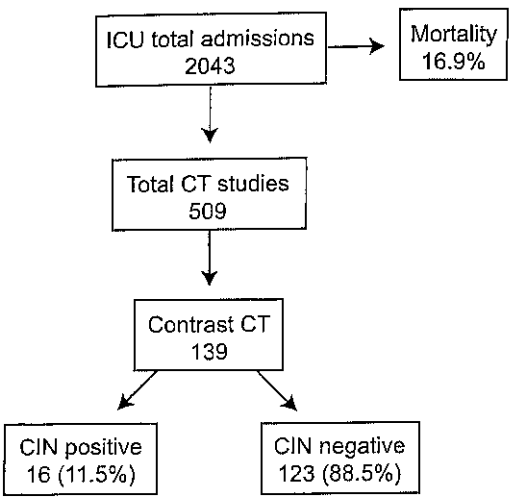

FIGURE 1: Patient flow diagram.

significantly higher in CIN positives (13.6±7.4 mmHg, P=0.04). However, there was no difference in baseline 24 hour fluid balance between CIN positive and CIN negative patients. No difference was found in oxygenation indices and haemoglobin at baseline or 24 hours (Table 2).

Multivariate analysis using logistic regression methods failed to identify any combination of conventional and ICU specific risk factors predictive for the development of CIN using this dataset. Risk factors included in the analysis were gender, admission diagnosis, age, weight, APACHE II, pre-existing renal impairment, volume of contrast of more than 1 ml/kg, background of hypertension, diabetes, co-administration of nephrotoxic medications, intra-arterial contrast administration, multiple studies, age, sepsis diagnosed at the time of the study, use of

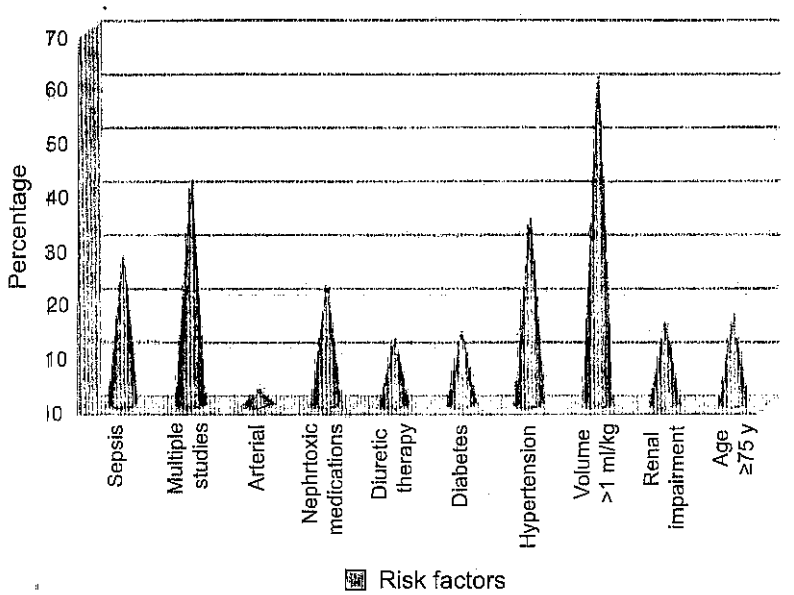

FIGURE 2: Conventional risk factors: percentages shown.

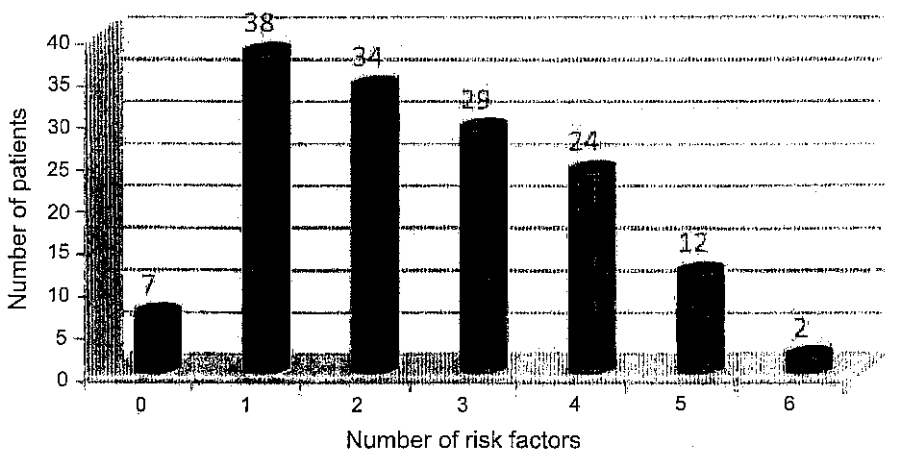

FIGURE 3: Frequency of multiple risk factors.

TABLE 2
Analysis of risk factors for contrast-induced nephropathy expressed as mean ± standard deviation

	CIN positive (n=16)	CIN negative (n=123)	*P* value
Gender			
Male	9	76	0.786
Female	7	47	
Age	66.5±12.8	59.8±19.4	0.181
Body mass index	26.9±5.0	27.0±7.3	0.957
APACHE II	22.5±11.9	19.4±8.1	0.177
Admission diagnosis			
Surgical	8	69	0.790
Medical	8	54	
Haemodynamics			
24 h fluid balance (ml)*	1621.2.4± 1770.6	1497.9± 2384.7	0.842
Vasopressors (μg/kg/min)	0.02±0.07	0.04±0.16	0.623
Inotropes (μg/kg/min)	0.62±1.9	0.13±0.91	0.085
MAP (mmHg)#	80.3±29.7	83.0±13.3	0.525
CVP (mmHg)#	13.6±7.4	10.9±4.5	0.040
Urinary output (ml/kg/h)**	0.92±1.3	1.43±1.4	0.169
Pre-study			
Fluid bolus (ml)	0.0±0.0	117.0±451.5	0.303
Oxygenation			
FiO_2#	0.46±0.23	0.41±0.13	0.194
S_aO_2	96.8±2.3	96.9±2.2	0.865
PEEP (cmH_2O)	3.7±3.5	4.5±3.5	0.391
Laboratory			
Haemoglobin (g/l)#	100.5±23.4	104.6±21.0	0.469
Baseline creatinine (μmol/l)	105.0±74.3	116.6±117.2	0.700
Creatinine 48 h (μmol/l)	201.8±160.0	101.8±92.8	<0.001
Contrast dose			
>1 ml/kg	13	72	0.103
<1 ml/kg	3	51	
Total volume (ml)	90.6±23.4	85.7±29.0	0.517
Renal impairment			
yes##	3	24	1.00
no	13	99	
Hypertension			
yes	8	40	0.175
no	8	83	
Diabetes mellitus			
yes	1	18	0.697
no	15	105	
Diuretic therapy			
yes	0	18	0.130
no	16	105	
Nephrotoxic medications			
yes###	3	28	1.00
no	13	95	
Arterial contrast			
yes	1	3	0.390
no	15	120	
Multiple studies			
yes	5	53	0.428
no	11	70	
Age >75 y			
yes	5	18	0.143
no	11	105	
Sepsis			
yes	2	37	0.235
no	14	86	

CIN=contrast-induced nephropathy, APACHE II=Acute Physiology and Chronic Health Evaluation II score, MAP=mean arterial pressure, CVP=central venous pressure, PEEP=positive end-expiratory pressure. * 24 hour fluid balance on the day of contrast CT, # Baseline measurement at/closest to time of CT, ** urine outputs averaged over six hours, ## renal impairment-creatinine at baseline 1.5×normal or urine output 0.5 ml/kg/h for six hours (pre-contrast administration), ### nephrotoxics considered were non-steroidals, aminoglycosides, amphoteracin, cyclosporine and ACE inhibitors.

TABLE 3
Outcomes of CIN positive and negative patients ± standard deviations

	CIN positive	CIN negative	*P* value
Length of stay (days)			
ICU	10.3±8.4	10.1±9.9	0.938 (95% CI 8.9-11.7)
Hospital	48.7±77.3	32.5±34.7	0.144 (95% CI 35.8-61.5)
ICU mortality (%)			
yes	5 (31)	16 (13)	0.068
no	11	107	
Hospital mortality (%)			
yes	8 (50)	32 (26)	0.074
Renal replacement therapy (%)			
yes	3 (19)	7 (6)	0.091
no	13	116	

CIN=contrast-induced nephropathy, ICU=intensive care unit, CI=confidence interval.

vasopressors and inotropes, mean arterial pressure, inspired oxygen fraction, creatinine level and urinary output. Only age analysis showed a P value of 0.04. (OR 1.041, 95% CI 1.002 to 1.081). Using age as the significative variable, the best single decision variable was age, with a 'splitting value' of 42.5 in a decision tree analysis.

The overall mortality of 139 patients undergoing contrast CT was 15.1% (Table 1). This was comparable with crude mortality of the general intensive care population admitted to these two hospitals in the Hunter region in 2006 (16.9%) (Figure 1).

CIN was associated with a higher ICU and hospital mortality (31% and 50%, respectively) compared to those who were CIN negative (13% and 26%, respectively) and the overall ICU population (16.9%). This difference trended towards statistical significance. CIN was not associated with increased ICU and hospital length of stay or need for renal replacement therapy (Table 3).

CIN in ICU is transient. All surviving CIN positive patients had complete recovery of renal function as measured by recent creatinine values and no patient is receiving long-term renal replacement therapy.

DISCUSSION

CIN has been well described in non-ICU patients, in particular those undergoing interventional cardiology procedures[2,7]. But there is little known of its incidence in the ICU population[10-12] and the clinical importance of small transient changes of creatinine is uncertain. However, interpretation of the CIN literature is already difficult in the non-ICU population, notwithstanding trying to extrapolate the findings to ICU patients. Some of the problems include a lack of a consensus definition of CIN, the use of diverse types of CM with differing nephrotoxicity and the use of a variety of preventive therapies employed to potentially avoid CIN.

Prevention of iatrogenic renal injury (which includes CIN) is an important part of ICU care. Recent large retrospective studies based on the new RIFLE classification of acute renal failure clearly show renal injury is associated with increased ICU and hospital resource use in critically ill patients and higher mortality[13-16]. Potentially important in relation to CIN, the RIFLE studies also highlight that small to moderate degrees of acute kidney injury are also associated with an increased risk of death.

This is the first Australian study of CIN in ICU patients. It shows an incidence of CIN of 11.5% (95% CI 6.2 to 16.8) in our general ICU population. This incidence falls between the reported incidence range of 5 to 50% in non-ICU settings[2,4,7,9]. This latter incidence range is too wide to allow the estimation of sample size for future studies in CIN. Our more refined estimation of the incidence of CIN in general ICU should assist future studies in this population. However, our CIN incidence rate is higher than those reported in the only three other published studies of CIN in the ICU setting. Haveman et al[10] reported an incidence of only 1.4% in a retrospective study of 321 surgical ICU patients, of similar age and APACHE II scores to ours, over a nine-year period. They performed routine pre- and post-CT hydration in order to prevent CIN. Later in their study, they also added prophylaxis with acetylcysteine to their protocol. In comparison, our ICU patients received iso-osmolar, non-ionic CM for CT and no specific preventive treatments. Only one of our patients was given acetylcysteine and the mean fluid bolus given to our patients was only 104 ml. It is tempting to conclude that the disparate incidences between their and our studies were due to their use of CIN prophylaxis. Instead, their low incidence may be due to the fact that Haveman's study used a different definition of CIN that excluded patients with a creatinine increase in the two days prior to the CT examination. When the original definition of Barrett and Parfrey[1] was applied as it was in our study, their ICU incidence of CIN rose to 13%. This is clearly similar to our incidence, despite their use of a CIN prevention protocol. This demonstrates the problem of using different definitions of CIN and suggests that their preventive protocols may not have been as effective as they suggest.

In the other reported studies of CIN in the ICU setting, Huber et al[11,12] set out to demonstrate the beneficial use of peri-contrast theophylline prophylaxis. They prospectively studied a series of 78 medical ICU patients, stratified for risk of CIN according to the presence of accompanying risk factors. They demonstrated a remarkably low overall incidence of CIN of 2% defined according to Barrettt and Parfrey's criteria. Even in patients classified as high risk, the incidence of CIN was only 3%. They implied that this proved the efficacy of their intervention. However they seemed to use a control incidence chosen from the literature. Although the profile of risk factors described was similar to those shown within our study, comparison of the two is difficult because they provided only of very limited baseline information about their patients. In a follow-up prospective randomised study, Huber[12] attempted to simultaneously compare three different peri-contrast prophylactic regimens. This study showed an overall incidence of CIN of

6%, ranging from 2 to 12% depending on which treatment patients received. The study was however methodologically flawed due to cross-over between patient groups, lack of proper randomisation and no intention to treat analysis.

The other aim of our study was to identify risk factors that might assist in the ability to predict those patients at risk of developing CIN in the ICU population. These, together with our more accurate incidence measure, should aid the future assessment into the usefulness of CIN preventive measures. We employed a set of conventional risk factors as identified in the literature and also attempted to identify more ICU specific risk factors. The latter were applied for the first time in our study. It is important to note that the majority of patients reviewed had multiple risk factors for the development of CIN. Conventional risk factors are commonly present in ICU patients. None of these risk factors was useful in predicting an increased risk of developing CIN. Among the ICU specific risk factors only the level of CVP prior to the CT examination demonstrated a statistically significant association to the development of CIN. Unfortunately we are unclear as to this risk factor's usefulness in clinical practice, as the other variables usually associated with achieving different CVP level, such as 24-hour fluid status and the requirement for vasopressors and inotropes, did not differ between CIN positive and negative patients.

Risk-scoring schemes to predict CIN have been devised in large studies of patients undergoing percutaneous coronary intervention[18], but none has been evaluated prospectively in intensive care. Our results suggest that conventional risk factors may not be helpful to predict CIN in ICU. The ICU specific variables we selected unfortunately did not predict the risk of developing CIN in ICU patients either, except possibly the level of CVP. This suggests that either our assumption that the patients' volume status, haemodynamic stability and oxygen delivery could be used as predictors of risk for developing CIN was incorrect, or that the measurements we selected to estimate these were not suitable. In addition, failure to identify risk factors predictive of CIN in this study is likely due to the small sample size and low event rate.

This study has important methodological limitations as follows. The use of retrospective analysis may have failed to identify patient selection biases. Medical records do not describe the decisions made by practitioners for the investigation of specific clinical problems. It is conceivable that patients deemed to be at high risk of CIN may have been denied contrast. Also, patients considered too unstable to be transported to the CT scanner may not have been captured in this study. It might be quite informative to study these two patient groups as they may represent a sicker group of ICU patients, with a higher prevalence of the risk factors, both conventional and ICU specific. The other major problem is the small sample size (patients who had contrast CT) and the low event rate (those who developed CIN). Multivariate analysis of risk factors associated with CIN failed to reveal variables predictive of CIN in our dataset, which may be due to some missing data in a setting of retrospective collection and the low event rate.

Taking the above into consideration, we have shown that CIN may be associated with an increase in ICU (31%) and hospital (50%) mortality that trended towards statistical significance in this small series. However, this study was not powered to assess secondary outcomes. In a large retrospective study of over 16,000 inpatients undergoing procedures with contrast media, the risk of death was 34% in those who developed CIN. Even after matching for co-morbidities, those who developed CIN had a 5.5-fold increased risk of death[3,19]. The numbers of CIN positive patients in this study are small. The five CIN positive patients who died in ICU represent only 4% of the 139 who received contrast and less than 1% of the total 509 CT scans performed in 2006.

Although our study is essentially hypothesis-generating, we believe it provides important information which should aid in the development of a larger prospective, randomised study of CIN in ICU including incidence, outcomes, relevant risk factors and preventive strategies.

CONCLUSION

In this first Australian study of CIN in ICU patients, we describe an incidence of CIN of 11.5% in a general ICU population. We cannot however, predict who will develop CIN in the ICU based on the use of described risk factors. Therefore we cannot recommend any change in the way we manage patients requiring CT with contrast. Further prospective studies are needed in the ICU to more clearly define the incidence of CIN and relevant risk factors. Only then may the efficacy of CIN prophylaxis in the ICU be assessed.

ACKNOWLEDGMENT

Drs Gordon Doig and Ursula Beckman made important contributions to the design and writing of this study.

REFERENCES

1. Barrett BJ, Parfrey PS. Prevention of nephrotoxicity induced by radiocontrast agents. N Engl J Med 1994; 331:1449-1450.
2. McCullough PA, Soman SS. Contrast-induced nephropathy. Crit Care Clin 2005; 21:261-280.
3. McCullough PA. Acute injury with iodinated contrast. Crit Care Med 2008; 36(Suppl 4):S204-211.
4. Van Praet JT, De Vriese AS. Prevention of contrast-induced nephropathy: a critical review. Curr Opin Nephrol Hypertens 2007; 16:336-347.
5. Uchino S, Kellum JA, Bellomo R, Doig GS, Morimatsu H, Morgera S et al. Acute renal failure in critically ill patients: a multinational, multicenter study. JAMA 2005; 294:813-818.
6. Bagshaw SM, Laupland KB, Doig CJ, Mortis G, Fick GH, Mucenski M et al. Prognosis for long-term survival and renal recovery in critically ill patients with severe acute renal failure: a population-based study. Crit Care 2005; 9:R700-709.
7. McCullough PA, Wolyn R, Rocher LL, Levin RN, O'Neill WW. Acute renal failure after coronary intervention: incidence, risk factors, and relationship to mortality. Am J Med 1997; 103:368-375.
8. Solomon RJ, Natarajan MK, Doucet S, Sharma SK, Staniloae CS, Katholi RE et al. Cardiac Angiography in Renally Impaired Patients (CARE) study: a randomized double-blind trial of contrast-induced nephropathy in patients with chronic kidney disease. Circulation 2007; 115:3189-3196.
9. Bartorelli AL, Marenzi G. Contrast-induced nephropathy. J Interv Cardiol 2008; 21:74-85.
10. Haveman JW, Gansevoort RT, Bongaerts AH, Nijsten MWN. Low incidence of nephropathy in surgical ICU patients receiving intravenous contrast: a retrospective analysis. Intensive Care Med 2006; 32:1199-1205.
11. Huber W, Jeschke B, Page M, Weiss W, Salmhofer H, Schweigart U et al. Reduced incidence of radiocontrast-induced nephropathy in ICU patients under theophylline prophylaxis: a prospective comparison to series of patients at similar risk. Intensive Care Med 2001; 27:1200-1209.
12. Huber W, Eckel F, Hennig M, Rosenbrock H, Wacker A, Saur D et al. Prophylaxis of contrast material-induced nephropathy in patients in intensive care: acetylcysteine, theophylline, or both? A randomized study. Radiology 2006; 239:793-804.
13. Hoste EAJ, Clermont G, Kersten A, Venkataraman R, Angus DC, De Bacquer D et al. RIFLE criteria for acute kidney injury are associated with hospital mortality in critically ill patients: a cohort analysis. Crit Care 2006; 10:R73.
14. Hoste AJ, Kellum JA. RIFLE criteria provide robust assessment of kidney dysfunction and correlate with hospital mortality. Crit Care Med 2006; 34:2016-2017.
15. Hoste EAJ, Schurgers M. Epidemiology of acute kidney injury: how big is the problem? Crit Care Med 2008; 36:S146-151.
16. Uchino S, Bellomo R, Goldsmith D, Bates S, Ronco C. An assessment of the RIFLE criteria for acute renal failure in hospitalized patients. Crit Care Med 2006; 34:1913-1917.
17. ACCP/SCCM Consensus Conference on Sepsis Definitions, 1992.
18. Mehran R, Aymong ED, Nikolsky E, Lasic Z, Iakovou I, Fahy M et al. A simple risk score for prediction of contrast-induced nephropathy after percutaneous coronary intervention: development and initial validation. J Am Coll Cardiol 2004; 44:1393-1399.
19. Levi EM, Viscoli CM, Horwitz RI. The effect of acute renal failure on mortality; a cohort analysis. JAMA 1996; 275:1489-1494. Conformité Européenne.