Oxygen therapy in non-intubated adult intensive care patients: a point prevalence study

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ABSTRACT

Background: Oxygen is commonly administered to intensive care unit patients. Although there is knowledge of how oxygen is administered to mechanically ventilated patients, there are few data about its use in non-intubated ICU patients.

Objective: To describe how oxygen therapy is prescribed, administered and monitored for non-intubated patients in New Zealand and Australian ICUs.

Design, participants and setting: Prospective, observational, binational, multicentre, 1-day point prevalence study of all adult patients in 40 New Zealand and Australian ICUs at 10 am on a study day.

Main outcome measures: We collected patient demographic data, 28-day mortality and details of oxygen therapy (oxygen therapy prescription, oxygen delivery device use and oxygen saturation targets).

Results: We audited 506 patients, of whom 178 (35.2%) were not intubated but receiving oxygen therapy; 59.5% were men. Their mean age was 57.3 years (SD, 18.8 years), mean Acute Physiology and Chronic Health Evaluation (APACHE) II score was 16.2 (SD, 7.3) and 47.2% were admitted after surgery. Most patients (66%) received oxygen via simple nasal cannulae, and patients also received oxygen via open face mask, nasal high-flow and non-invasive ventilation. A documented prescription for oxygen therapy was in place for 24.4% of patients, and we considered 7% to be complete and comprehensive.

Conclusions: Oxygen therapy is commonly administered to non-intubated adult patients in New Zealand and Australian ICUs. Most patients received oxygen by simple nasal cannulae, and oxygen therapy prescriptions were often absent or incomplete. We advise continuing education to ensure that oxygen is prescribed, administered and documented correctly.

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Oxygen is one of the most widely available and prescribed therapeutic drugs in medicine.[1] Intensive care unit patients are usually given supplemental oxygen to avoid or treat hypoxaemia or as routine postoperative care. Optimisation of oxygen delivery remains the cornerstone of treatment for common ICU syndromes such as sepsis, multiorgan dysfunction, acute respiratory distress syndrome and acute lung injury.[2] When administered correctly, oxygen may be life-saving, but if given without careful management it can lead to adverse effects and poor patient outcomes.[1]

The risks associated with hypoxaemia are well recognised, but there is growing evidence that prolonged hyperoxia should also be avoided, as high fractions of inspired oxygen may cause damage to the lungs and have other detrimental systemic effects.[3-5] Furthermore, findings from previous intensive care-based studies have shown that oxygen is poorly prescribed, monitored and administered in the critical care setting.[6-8] To optimise the safe and effective administration of oxygen, there should be a prescription detailing the oxygen flow rate, concentration and delivery method, and a method of assessing treatment should be available.[1,7]

There is currently little published evidence to guide ICU clinicians in their selection and use of oxygen delivery devices or the prescription of oxygen therapy for non-intubated patients.[9] In 1999, Mao et al surveyed 52 medical directors of ICUs in 48 institutions via a structured postal questionnaire.[10] All respondents considered oxygen toxicity to be a concern, yet only 71% reported assessing tissue oxygenation on a routine basis, as there was considerable variation in the attitudes, beliefs and self-reported practice of oxygen therapy. Two Australian surveys have been published describing the attitudes of ICU doctors and nurses to oxygen therapy.[11,12] Eastwood et al, in an online survey of intensivists, suggested that variability in oxygen therapy practice is likely to continue until there is evidence from clinical trials to support clinical practice guidelines, and concluded that there is a need to further explore factors that influence clinical decisions about oxygen therapy.[11] A large international study providing information on the characteristics and outcomes in 15 757 adult patients in 20 countries receiving mechanical ventilation was performed in 2002 by Esteban et al.[13] Although this prospective cohort study detailed current practice in intubated patients in the ICU, it does not provide evidence on current oxygen therapy practice in non-intubated patients.

Table 1. Estimated inspired oxygen concentration

Nasal cannulae		Face mask	
Flow rate (L/min)	Estimated FIO_2 (%)	Flow rate (L/min)	Estimated FIO_2 (%)
1	24%	5	30%
2	28%	6	35%
3	32%	7	40%
4	36%	8	45%
5	40%	9	50%
6	44%	10	55%

FIO_2 = fraction of inspired oxygen.

There appears to be minimal literature describing oxygen therapy in non-intubated adult ICU patients. In response, we sought to describe how oxygen therapy was prescribed, administered and monitored to non-intubated ICU patients.

Methods

Design and approval

Our observational study was embedded in the Australian and New Zealand Intensive Care Society Clinical Trials Group (ANZICS CTG) point prevalence program (PPP). Infrastructure support for the ANZICS CTG PPP was provided by the George Institute for Global Health. The PPP is a prospective, 1-day, binational research initiative of the ANZICS CTG used by researchers to support avenues of clinical enquiry. Ethics committee approval to conduct the audit and for collection of data related to the study was obtained by all sites. The need for informed patient consent was waived by each committee.

Data collection

Data for this study were collected on 13 November, 21 November or 6 December 2012. A choice of dates allowed flexibility for sites to participate. Trained research staff collected data on all adult patients (aged 16 years or older) in their ICU at 10 am on the study day. General demographic data (eg, age, sex and admission diagnosis) and care and therapeutic intervention data for 24-hour and 28-day mortality were collected. For all non-intubated patients, the oxygen therapy data collected included:

- oxygen prescription (oxygen flow rate or inspired oxygen concentration, oxygen delivery device, level of monitoring and target oxygen saturation)
- method of administration (delivery device use and oxygen flow rate or inspired oxygen concentration)
- monitoring of therapy (presence of arterial or cutaneous oxygen saturation monitoring).

Details of the highest and lowest partial pressure of oxygen (Pao_2) and carbon dioxide ($Paco_2$) in the previous 24 hours were recorded in patients who had had routine arterial blood gas sampling performed. The fraction of inspired oxygen concentration (FIO_2) was measured for high-flow devices and was estimated for low-flow devices, according to Table 1.[14] A survey of ICUs about oxygen therapy protocols and devices available for oxygen therapy within the unit was sent to each site.

Data analysis

Data were entered by the participating sites into a single electronic database managed by The George Institute for Global Health. Data for this study were extracted into Excel (Microsoft) spreadsheets, and then entered into Stata, version 12 (StataCorp) for analysis. Descriptive statistics were used for all clinical and demographic data.

Table 2. Baseline patient characteristics of non-intubated patients receiving oxygen therapy (*N* = 178)

Characteristic	Data (% unless otherwise stated)
Mean age, years (SD)	57.3 (18.8)
Sex (male), number (%)	110 (59.5%)
Mean body weight,* kg (SD)	81.1 (24.3)
Mean APACHE II score (SD)	16.2 (7.3)
ICU admission source, number (%)	
Operating theatre	84 (47.2%)
Emergency department	42 (23.6%)
Hospital ward	33 (18.5%)
Transfer from other hospital	17 (9.6%)
Transfer from other ICU	2 (1.1%)
APACHE II diagnostic categories, number (%) (*N* = 175)	
Cardiovascular	38 (21.7%)
Respiratory	35 (19.7%)
Gastrointestinal	29 (16.3%)
Neurological	15 (8.4%)
Sepsis	18 (10.1%)
Trauma	11 (6.2%)
Renal/genitourinary	7 (3.9%)
Other	22 (12.4%)
Mortality 28 days after study day, number (%)	11 (6.2%)

APACHE = Acute Physiology and Chronic Health Evaluation.
ICU = intensive care unit. * Body weight is estimated or measured.

Results

Cohort characteristics

In total, 506 patients were enrolled from 40 New Zealand and Australian ICUs. Of these patients, 178 (35.2%) were not intubated but were receiving oxygen therapy and have been included in the analysis. The mortality of non-intubated patients who received oxygen therapy at Day 28 was 6.2%. Baseline patient characteristics of the non-intubated patients receiving oxygen therapy are shown in Table 2. When compared with the intubated patients, non-intubated patients on the study day were older (mean, 61.2 years [SD, 17.5 years] versus mean, 57.3 years [SD, 18.8 years]; $P = 0.02$) and had lower Acute Physiology and Chronic Health Evaluation II scores (mean, 16.2 [SD, 7.3] versus mean, 21.4 [SD, 7.2]; $P < 0.001$).

Indication for oxygen therapy

The primary indications for oxygen therapy were ($N = 177$):

- hypoxaemia (measured by peripheral oxygen saturation) in 30.5% of patients ($n = 54$)
- routine therapy (not protocolised) in 29.9% of patients ($n = 53$)
- hypoxaemia (measured by arterial blood gas analysis) in 23.7% of patients ($n = 42$).
- protocolised care in 11.9% of patients ($n = 21$).

Figure 1. Oxygen therapy device used at time of survey

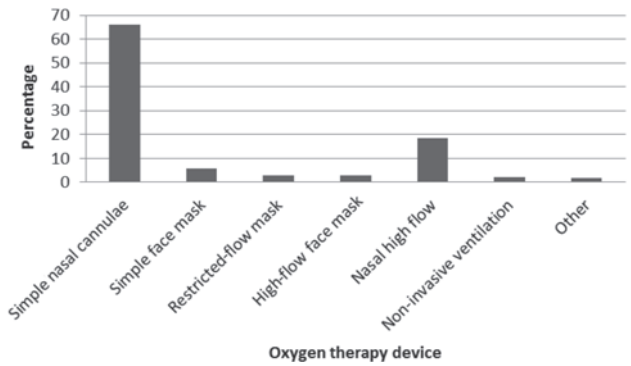


Figure 2. Reasons cited for oxygen therapy device used

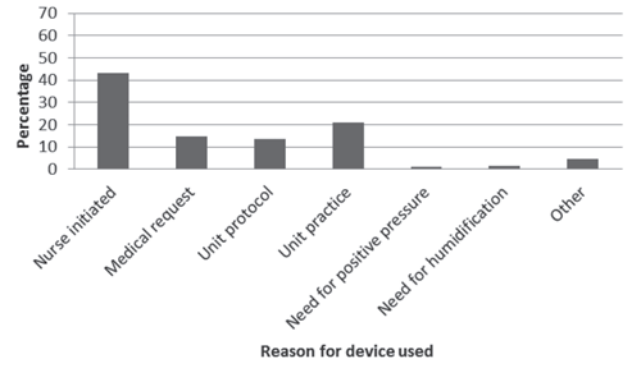


Table 3. Oxygen therapy prescriptions ($N = 43$)

Oxygen therapy prescription	*n (%)*
Oxygen flow rate	22 (51)
Inspired oxygen concentration	16 (37)
Delivery device to be used	31 (72)
Monitoring required	12 (28)
Target oxygen saturation parameters	28 (65)
Patients receiving therapy as prescribed	41 (95)

Oxygen delivery devices

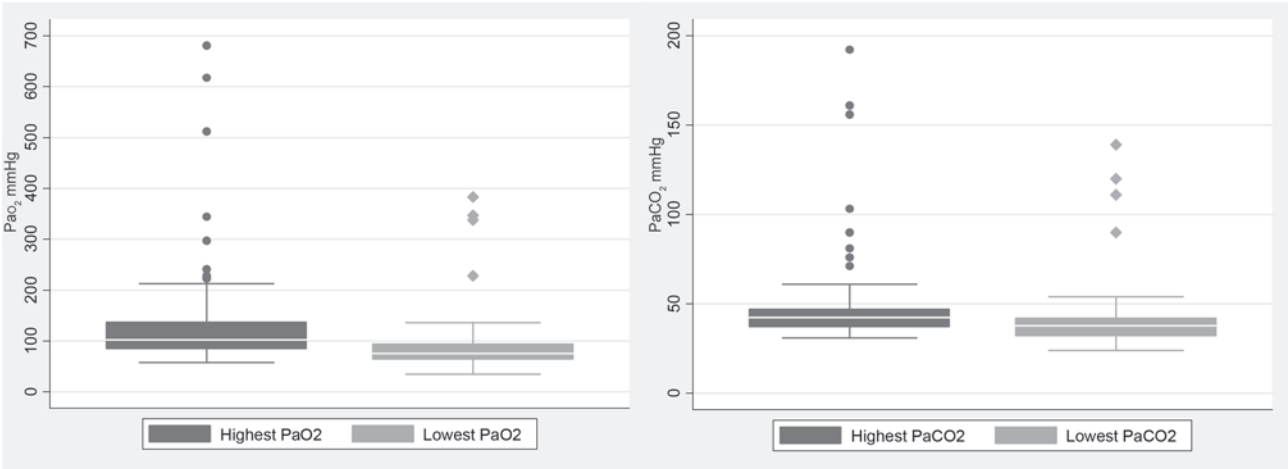
Of the 506 eligible participants 208 patients (41.1%) were not mechanically ventilated. Of these non-ventilated patients, 178 (85.6%) were receiving oxygen therapy at the time of the survey. Of these, 94 patients (52.8%) had been mechanically ventilated previously during this ICU admission. Of the 178 patients receiving supplemental oxygen: 117 (65.7%) received it via simple nasal prongs, 10 (5.6%) via simple face mask, five (2.8%) via restricted-flow mask, five (2.8%) via high-flow mask, 33 (18.5%) via nasal high-flow (NHF), four (2.2%) via non-invasive ventilation (NIV) and four (2.2%) via other devices (Figure 1).

There were no differences in baseline demographics or indications for current oxygen therapy device used between the group receiving oxygen therapy via simple nasal prongs when compared with all others receiving oxygen therapy. There was a significant difference in the mean F_{IO_2} when comparing those using simple nasal prongs to all others (30.5% [SD, 7.9%] versus 43.3% [SD, 14.9]) There was also a significant difference in mean ages of those comparison groups (59.8 years [SD, 19 years] versus 53.7 years [SD, 17.6 years]). The primary reasons the device in use had been employed is shown in Figure 2.

Oxygen therapy prescription

Patients who were receiving supplemental oxygen had a mean estimated F_{IO_2} of 34.2% (SD, 11.9%; range, 24%–100%). Forty-five patients (25.4%) were receiving oxygen therapy which was humidified, all by means of an active humidification device, such as a water bath or heated humidifier. Most of these patients (73.3%) were receiving NHF oxygen therapy, and all of those received humidification. Of the patients not receiving humidified oxygen

Figure 3. Comparison of highest and lowest Pao_2 and $Paco_2$ values in study patient



Pao_2 = arterial partial pressure of oxygen. $Paco_2$ = arterial partial pressure of carbon dioxide.

therapy, two were receiving NIV. The remaining patients were using a restrictive flow mask, eg, Venturi mask, simple face mask or simple nasal cannulae.

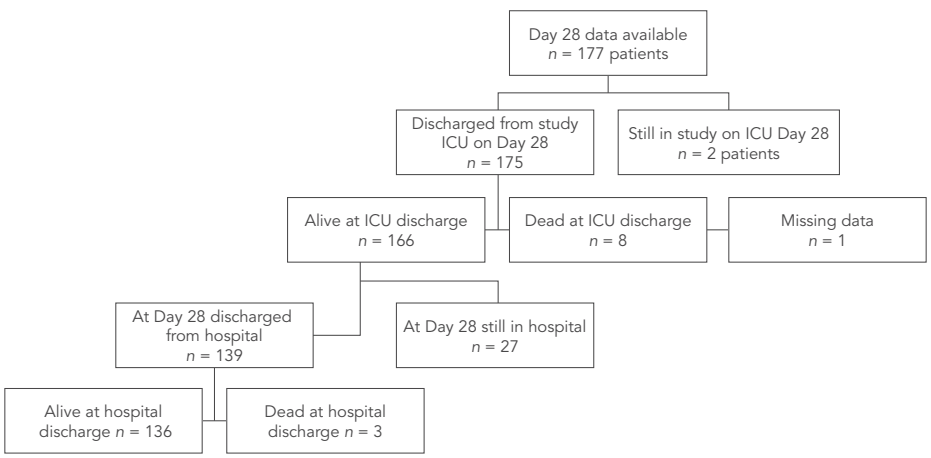
When we assessed oxygen therapy prescriptions, we found that 43 patients (24.4%; $N = 176$ due to missing data) had a current written therapy order, with only three (7%) covering all suggested parameters for a complete oxygen therapy prescription. Table 3 shows how oxygen therapy prescriptions were detailed.

Monitoring oxygen therapy

Overall, 73 patients (41.2%) had an oxygen saturation target documented. The mean lower oxygen saturation target was 92.5% (SD, 2.8%; range 80%–99%), and the mean upper oxygen saturation target was 94.4% (SD, 3.5%; range, 90%–99%).

For patients with arterial lines in situ for at least part of the previous 24 hours, the highest and lowest arterial blood gas measurements of Pao_2 and $Paco_2$ for 108 patients were available for analysis. The mean highest Pao_2 was 129 mmHg (SD, 94 mmHg; range, 58–681 mmHg), the mean lowest Pao_2 was 88 mmHg (SD, 52 mmHg; range, 35–383 mmHg), the mean highest $Paco_2$ was 47 mmHg (SD, 23 mmHg; range, 31–192 mmHg), and the mean lowest $Paco_2$ was 40 mmHg (SD, 16 mmHg; range, 24–139 mmHg). Figure 3 shows the mean and standard deviations for the highest and lowest Pao_2 and $Paco_2$ recorded in the 24 hours before 10 am on the study day.

Figure 4. Patient status at Day 28 of oxygen therapy study



ICU = intensive care unit.

Of the patients receiving oxygen therapy, 106 (59.9%*) had an arterial line in situ, 161 (91%*) had continuous respiratory rate monitoring available, 176 (99.4%*) had continuous pulse oximetry monitoring in situ and 173 (98.3%*) had continuous electrocardiographic monitoring in place. All patients had one or more of the above monitoring devices in situ. (*$N = 177$ due to missing data.)

28-day patient outcome

Mortality data at Day 28 were also assessed (see Figure 4). Day 28 data were available for 177 patients. Of these, 175 patients

(98.9%) had been discharged from the study ICU and two patients (1.1%) remained in the ICU. Eleven patients (6.2%) had died by Day 28 in the ICU or between ICU discharge and Day 28.

Data about ICUs

Twenty-six ICUs (65%) submitted data detailing the availability of oxygen therapy protocols and devices available for use within their unit. Only 13 of these ICUs (50%) had a protocol to guide oxygen therapy in the unit. All 26 ICUs used NHF oxygen therapy, with 16 (61.5%) having a protocol to guide use of this therapy. The mean starting flow rate for NHF therapy recommended by these protocols was 38 L/minute (SD, 5 L/minute; range, 30–50 L/minute) and the mean highest flow rate recommended was 57 L/minute (SD, 12 L/minute; range, 35–70 L/minute). NIV was actively humidified by ICUs 100% of the time in 16 units (61.5%), 50%–99% of the time in nine units (34.6%), and never in one unit (3.8%). Some hospital wards (including respiratory, cardiothoracic, neurology, oncology and ear, nose and throat wards and coronary care units) were identified as being able to receive patients receiving humidified oxygen therapy, NHF or non-invasive oxygen therapy.

Discussion

Key findings

In our point prevalence study, describing how oxygen therapy is prescribed, administered and monitored for non-intubated adult patients admitted to New Zealand and Australia ICUs, we made three key findings:

- On the study day, 85.6% of non-intubated adult patients in the ICUs were receiving oxygen therapy, and this sometimes resulted in supraphysiological arterial oxygenation.
- Most patients (66%) received oxygen via simple nasal cannulae, and fewer patients received it via face masks, NHF or NIV.
- Oxygen therapy was poorly prescribed and failed to meet the recommended standards.

Comparison with previous studies

The patient cohort we describe is similar to that described in other ICU studies, internationally and from Australasia.[13,15-17] To the best of our knowledge, no other study has described how oxygen therapy is administered to non-intubated patients in the ICU, therefore comparisons of the range of delivery devices employed and the reasons for oxygen therapy cannot be made. Oxygen therapy has been described in patients on hospital wards and in emergency departments but poorly described in the ICU.[18-21]

Our study confirms that supplemental oxygen administration is almost universal in non-intubated patients in ICUs. Despite the availability of monitoring for oxygenation parameters, including pulse oximetry and arterial blood gas analysis, there is little apparent attempt to titrate oxygen to physiological levels.

In our study, only 24.4% of patients had a prescription for oxygen therapy, meaning that 75.6% were receiving oxygen therapy that was not prescribed. Failure to have a documented oxygen therapy prescription may result in inappropriate administration of oxygen and may contribute to prolongation of therapy that is no longer required. Differing results have been found in other studies, eg, in one study, only 8% of patients receiving oxygen therapy in a medical ward had an oxygen prescription,[7] and in another study 93.4% had a current prescription.[18] The criteria we used to determine if a prescription covered all necessary components is consistent with other studies which have assessed similar points for inclusion.[19]

Our findings support previously identified concerns about the safety of oxygen administration in New Zealand and Australian ICUs.[7,9,19] Although they receive high-level monitoring, ICU patients still need a current prescription for oxygen therapy in order to ensure high-quality care. Further training in oxygen therapy prescription is required, and more frequent surveys of practice should be undertaken, with feedback of results to individual sites. Results could be used as the basis for future quality assurance projects.

A possible reason oxygen therapy may be poorly prescribed is that most ICUs use large-format bedside charts, which may not have a specific area for oxygen therapy, or the allocated space may be small or located on the reverse side of the chart. Oxygen therapy-related variables are also often termed "ventilation orders" and may be better termed "oxygen therapy" to include intubated and non-intubated patients. Many institutions are now moving towards prescribing oxygen therapy on combination drug charts. Two studies have shown that the institution of specific documentation for prescribing oxygen results in improved prescription.[19,22] We were pleased to find (as did a previous audit[19]) that all patients had some form of oxygen monitoring in place and that essentially all had continuous pulse oximetry in situ. However, it was unclear how often these devices were being used to wean patients off oxygen.

Strengths and limitations

Our study has several strengths, including a prospective design, standardised data-collection methods, robust outcomes and the capture of data from multiple sites from two countries. To the best of our knowledge, this is the first study of the use of oxygen in an undifferentiated, non-intubated adult patient population in the ICU.

The actual F_{IO_2} delivered using low-flow systems (or any systems in which a patient's peak inspiratory flow exceeds the flow provided by the device) is difficult to estimate accurately and varies according to patient characteristics (including respiratory rate, peak inspiratory flow and mouth-open breathing versus mouth-closed breathing).[23,24] Despite this, we employed a widely used conversion chart to convert device and flow data into F_{IO_2}.[14] In clinical practice, the actual F_{IO_2} delivered in the range possible for low-flow devices (0.24–0.55) is less important than the ability to titrate oxygen to a measured end point. In our study, there was little evidence that down-titration, in particular, is widely practised.

Our findings should be interpreted with caution as they represent a snapshot of oxygen therapy administered to non-intubated patients in the ICU and cannot be compared with other longitudinal data. Also, depending on the clinical condition of the patients on the study day, the study cohort may not be representative of the broader ICU population on another day. However, because oxygen therapy is essentially given to all ICU patients, our study findings can be generalised to a degree to reflect oxygen therapy practice in other New Zealand and Australian ICUs.

Conclusion

We found that a large proportion of ICU patients were receiving oxygen therapy but that it was rarely titrated to monitored end points. The most commonly used oxygen delivery device were simple nasal cannulae. Generally, oxygen therapy was poorly prescribed and prescriptions did not meet standard recommendations. These findings are important for understanding current oxygen therapy practice in ICUs and will inform future interventional clinical trials of oxygen therapy. We advise continuing education interventions to ensure that oxygen therapy is prescribed, administered and documented correctly.

Competing interests

None declared.

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Appendix. Site investigators for study of oxygen therapy in non-intubated adult intensive care patients (sites in Australia unless otherwise stated)

Albury Wodonga Health, Albury, NSW: C Mashonganyika, C Maher, E Brom
Auckland City Hospital, Cardiothoracic and Vascular Intensive Care Unit, Auckland, New Zealand: R Parke, E Gilder, L McCarthy
Auckland City Hospital, Department of Critical Care Medicine, Auckland, New Zealand: C McArthur, L Newby, K Benefield, Y Chen
Austin Hospital, Melbourne, VIC: R Bellomo, L Peck, H Young
Bendigo Hospital, Bendigo, VIC: J Fletcher, J Smith
Calvary Mater Hospital, Newcastle, NSW: K Ellem, S Meaks
Central Gippsland Health Service, VIC: J Dennett, H Connor, T Coles
Christchurch Hospital, Christchurch, New Zealand: S Henderson, D Knight, J Mehrtens
Concord Hospital, Sydney, NSW: D Milliss, H Wong
Flinders Medical Centre, Adelaide, SA: S Verghese, E Ryan, C Hannan, S Clarke
Geelong Hospital, Geelong, VIC: C Cattigan, T Elderkin, A Bone, T Salerno, M Fraser
Gold Coast Hospital, Southport, QLD: B Richards, M Tallott
John Hunter Hospital, Newcastle, NSW: P Harrigan, M Hardie, E Pollock
Lyell McEwin Hospital, Adelaide, SA: R Ramadoss, J Wood
Mater Health Services, Brisbane, QLD: A Schibler, C Stocker, S Mayfield
Middlemore Hospital, Auckland, New Zealand: A Williams, A Tilsley, R Song, L Rust
Nepean Hospital, Penrith, NSW: I Seppelt, L Weisbrodt
North Shore Hospital, Auckland, New Zealand: J Liang, J Bell
North Shore Private Hospital, Sydney, NSW: A Delaney, S Ash, D Hogben
Princess Margaret Hospital for Children, Perth, WA: S Erickson, J Abe
Royal Adelaide Hospital, Adelaide, SA: H Mcbeth, J Rivett, S O'Connor
Royal Children's Hospital, Brisbane, QLD: A Slater, D Long, S Kendall
Royal Children's Hospital, Melbourne, VIC: W Butt, C Delzoppo
Royal Hobart Hospital, Hobart, TAS: A Turner, D Cooper, R McAllister
Royal Melbourne Hospital, Melbourne, VIC: C MacIsaac, D Barge
Royal North Shore Hospital, Sydney, NSW: S Bird, A O'Conner
Royal Perth Hospital, Perth, WA: S Webb, J Chamberlain
Royal Prince Alfred Hospital, Sydney, NSW: D Gattas, H Buhr, M Keir
Sir Charles Gairdner Hospital, Perth, WA: S Baker, B Roberts
St George Hospital, Sydney, NSW: J Myburgh, J Miller, R Sidoli, D Inskip
St Vincent's Hospital, Melbourne, VIC: J Santamaria, R Smith, J Holmes
Starship Children's Health, Auckland, New Zealand: J Beca, E Segedin, C Sherring, M Rea, T Bushell
Sydney Children's Hospital, Sydney, NSW: M Morritt, G Williams, J Young
Tauranga Hospital, Tauranga, New Zealand: T Browne, R Atkin, J Goodson
The Alfred Hospital, Melbourne, VIC: A Davies, S Vallance, J Board
The Canberra Hospital, Canberra, ACT: I Mitchell, H Rodgers, E Taylor, E Fulton
The Northern Hospital, Melbourne, VIC: G Duke, J Green, A Casamento, M Park, O Burgess
The Queen Elizabeth Hospital, Adelaide, SA: S Peake, T Williams, K Kurenda
Waikato Hospital, Hamilton, New Zealand: A Forrest, J Durning, M La Pine
Wellington Hospital, Wellington, New Zealand: D Dinsdale, L Andrews, D Mackle, J Ongley, J Tang-Hickey
Western Health, Melbourne, VIC: C French, S Bates
Westmead Hospital, Sydney, NSW: V Nayyar, C Skelly, J Kong
Wollongong Hospital, Wollongong, NSW: M Sterba, B Johnson