Intravenous (IV) fluid administration is a nearly ubiquitous intervention in hospitalised patients. It is used to maintain euvolaemia in fasting patients, to replace physiological and pathophysiological fluid losses, to deliver medications and to manage haemodynamic instability. The consumption of IV fluids is expected to increase, and the global market is expected to be worth an estimated $7.2 billion by 2017.

Crystalloid solutions such as 0.9% sodium chloride solution, balanced solutions such as compound sodium lactate solution, and acetated solutions such as Plasmalyte are used in a variety of clinical situations. Artificial colloid solutions such as substituted hydroxyethyl starch (HES) (Voluven, Volulyte and StarQuin), succinylated gelatin (Gelofusine) preparations, and natural colloids such as various albumin solutions are typically used for fluid resuscitation. The type of fluid used appears to vary depending on clinician preference, cost, local guidelines and availability, and clinical requirements.

Despite the importance of IV fluid therapy, it remains unclear whether and how fluid consumption varies in different regions and countries. It is also uncertain whether such differences in fluid consumption are of sufficient magnitude to warrant further investigation, or whether these differences are dependent on the type of fluid being investigated. Finally, there are no studies on how such changes have evolved over time. We aimed to describe the geographic and temporal differences in fluid consumption across Australia and New Zealand.

**Methods**

We conducted a retrospective ecological study examining current regional and temporal trends in fluid administration across Australia and New Zealand over the periods 2012–2013 and 2013–2014. The human research ethics committees of Monash University and the Austin Hospital approved the study (CF14/2949-2014001616 and LNR/14/Austin/408).

**Data sources**

**Australian and New Zealand demographic data**

National and state population data were accessed through the relevant government agency publications. For Australia, the state and territorial populations for 2012 and 2013 were taken from the Australian Bureau of Statistics December 2014 demographic statistics release. We used the 2013 Population Estimates and Projections report from Statistics New Zealand to obtain data on the national population of New Zealand for 2012 and 2013.

**Australian and New Zealand fluid sales data**

Data on sales of crystalloids and artificial colloids in New Zealand and Australia over the periods 1 June 2012 to 31 May 2013 and 1 June 2013 to 31 May 2014 were obtained from Baxter Healthcare (Sydney, NSW, Australia). These data were used as a surrogate for fluid consumption. The data were originally collected by IMS Health (Danbury, Conn, United States), a large information technology company.
that specialises in provision of detailed health care data from more than 100,000 suppliers in over 100 countries to commercial and health care services. These are likely to be the most comprehensive sales data available, covering the entire IV fluid sector. Baxter Healthcare paid for data from IMS to use for sales forecasting purposes and market share estimation, which is standard practice in the health care industry. No information was available on 5% dextrose, 4% dextrose/0.18% saline or hypertonic saline. Baxter Healthcare provided us with these data for the purposes of this research.

Within Australia and New Zealand, Baxter Healthcare is the sole supplier of crystalloids but not of colloids. CSL is the sole supplier of albumin solutions, Fresenius-Kabi is the sole supplier of starch solutions, and B. Braun is the sole supplier of gelatin solutions.

Baxter Healthcare, using proprietary predictive modelling, imputed the artificial colloid sales data for New Zealand over the 2013–2014 period. As the same regional administration and sales team provides service in the Australian Capital Territory and New South Wales, Baxter Healthcare amalgamated the data for these two regions. Regional data for New Zealand were unavailable and it was treated as a single administrative area. Data were corrected for veterinary sales where possible; these were only available at a national level, and only for crystalloid solutions.

In Australia, naturally derived colloid solutions of 4% and 20% human albumin are freely available from the Australian Red Cross Blood Service as a by-product of blood product manufacture. We obtained data on their delivery from the Red Cross, the National Blood Authority and CSL.

Data handling

The total volume of crystalloids and colloids purchased in both Australia and New Zealand was calculated by multiplying the volume per unit by the number of units sold. This was repeated for New Zealand alone and the individual states and territories, and for each individual type of fluid. The volume purchased per capita was also calculated.

### Table 1. Population demographics and gross intravenous fluid sales (L), by region and fluid type

<table>
<thead>
<tr>
<th>Region</th>
<th>Population</th>
<th>Saline</th>
<th>CSL</th>
<th>Acetate</th>
<th>Total crystalloids</th>
<th>20% albumin</th>
<th>4% albumin*</th>
<th>Gelofusine**</th>
<th>Starch***</th>
<th>Total colloids</th>
<th>Total fluids</th>
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<tbody>
<tr>
<td>2012–2013</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NZ</td>
<td>4 435 700</td>
<td>1 071 466</td>
<td>301 208</td>
<td>372 627</td>
<td>1 745 301</td>
<td>873</td>
<td>5 447</td>
<td>6 815</td>
<td>10 974</td>
<td>24 108</td>
<td>1 769 409</td>
</tr>
<tr>
<td>AUS</td>
<td>22 917 637</td>
<td>7 350 401</td>
<td>3 835 018</td>
<td>201 513</td>
<td>11 386 932</td>
<td>14 903</td>
<td>112 922</td>
<td>48 677</td>
<td>25 967</td>
<td>202 468</td>
<td>11 589 400</td>
</tr>
<tr>
<td>ACT, NSW</td>
<td>7 734 777</td>
<td>2 518 316</td>
<td>1 455 359</td>
<td>83 226</td>
<td>4 056 901</td>
<td>5 341</td>
<td>31 134</td>
<td>6 863</td>
<td>8 422</td>
<td>51 759</td>
<td>4 108 660</td>
</tr>
<tr>
<td>VIC</td>
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<td>17 44 769</td>
<td>1 101 160</td>
<td>15 819</td>
<td>2 861 748</td>
<td>3 474</td>
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<td>8 621</td>
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<td>87 573</td>
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<td>3 291</td>
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<td>506 603</td>
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<td>1 111</td>
<td>6 862</td>
<td>15 636</td>
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<td>12 514</td>
<td>7 957</td>
<td>590</td>
<td>22 324</td>
<td>780 130</td>
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<tr>
<td>TAS</td>
<td>512 475</td>
<td>206 249</td>
<td>119 829</td>
<td>804</td>
<td>326 882</td>
<td>290</td>
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<td>492</td>
<td>73</td>
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<td>112 889</td>
<td>19 683</td>
<td>7 080</td>
<td>139 652</td>
<td>132</td>
<td>1 037</td>
<td>100</td>
<td>0</td>
<td>1 269</td>
<td>140 921</td>
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<tr>
<td>AUS and NZ</td>
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<td>8 421 867</td>
<td>4 136 226</td>
<td>574 140</td>
<td>13 132 232</td>
<td>15 776</td>
<td>118 369</td>
<td>55 491</td>
<td>36 941</td>
<td>226 577</td>
<td>13 358 809</td>
</tr>
</tbody>
</table>

| 2013–2014  |            |        |     |         |                   |              |             |              |            |                |              |
| NZ         | 4 475 100  | 1 231 277 | 381 663 | 431 465 | 2 044 405       | 993          | 6 184      | 5 111         | 6 807      | 19 095         | 2 063 500    |
| AUS        | 23 307 564 | 7 314 712 | 4 144 483 | 279 977 | 11 739 172     | 14 913       | 115 567    | 46 375        | 5 554      | 182 408        | 11 921 580   |
| ACT, NSW   | 7 849 120  | 2 540 654 | 1 612 889 | 100 613 | 4 254 155     | 5 397        | 29 701     | 5 962         | 3 338      | 44 397         | 4 298 552    |
| VIC        | 5 787 086  | 1 642 750 | 1 100 928 | 20 019  | 2 763 697     | 3 428        | 29 608     | 12 283        | 734        | 46 051         | 2 809 748    |
| QLD        | 4 687 417  | 1 735 309 | 870 888  | 122 829 | 2 729 026     | 3 115        | 34 416     | 5 519         | 927        | 43 976         | 2 773 002    |
| WA         | 2 549 145  | 650 281  | 556 551  | 11 184  | 1 218 016     | 1 105        | 6 930      | 15 416        | 422        | 23 873         | 1 241 888    |
| SA         | 1 67 7062 | 581 263  | 281 815  | 10 740  | 873 818       | 1 360        | 11 941     | 6 498         | 127        | 19 926         | 893 744      |
| TAS        | 513 927   | 202 718  | 128 363  | 996      | 322 077       | 357          | 2 105      | 627           | 7          | 3 095          | 335 172      |
| NT         | 243 807   | 119 090  | 20 943   | 19 836  | 159 869       | 153          | 868        | 70            | 0          | 1 090         | 160 959      |
| AUS and NZ | 27 782 664 | 8 545 989 | 4 526 146 | 711 442 | 13 783 577    | 15 906       | 121 751    | 51 486        | 12 360     | 201 503        | 13 985 080   |

CSL = compound sodium lactate. NZ = New Zealand. AUS = Australia. ACT = Australian Capital Territory. NSW = New South Wales. VIC = Victoria. QLD = Queensland. WA = Western Australia. SA = South Australia. TAS = Tasmania. NT = Northern Territory. * Australian, NZ, and Australian + NZ crystalloid values adjusted to account for national sales to veterinary agencies. † From government data. ‡ 0.9% sodium chloride solution. § PlasmaLyte (proprietary acetated solution). ¶ 20% human albumin solution. ** 4% human albumin solution. †† 4% succinylated gelatin solution. ‡‡ 6% hydroxyethyl starch + 10% pentastarch.
For the purposes of comparison, total fluid sales across the whole of Australia and New Zealand were treated as the index population. Sales of Hartmann’s solution and compound sodium lactate solution were combined under the heading of compound sodium lactate, and Voluven, Volulyte and StarQuin 6% solution sales, as well as sales of a very small quantity of pentastarch in New Zealand in 2012–2013, were combined under the heading of starch.

Statistical analysis
We performed statistical analyses using Stata, version 13 (StataCorp) and calculated simple proportions and percentages. The Wilcoxon signed-rank test was used to identify significant differences in the sales of each fluid type between the two periods across all regions. A two-sided P value of 0.05 was considered to be statistically significant.

Results
Demographics and gross fluid sales data
The gross national and regional fluid sales and population data are shown in Table 1. More than 13.3 million litres of IV fluid were sold (and probably consumed) in Australia and New Zealand in the 2012–2013 period, and more than 13.9 million litres in 2013–2014. Crystalloid sales dwarfed colloid sales, with only 227 000 L of colloid fluids being consumed in 2012–2013 and 201 000 L in 2013–2014 (Table 1, Figure 1).

Regional differences in overall fluid consumption
The consumption of fluid varied in quantity and composition for the 2012–2013 and 2013–2014 periods according to region. The relative proportions of the individual fluid types consumed in each region over these periods are shown graphically in Figures 1 and 2. In 2012–2013, 523 mL of IV fluid were consumed per capita among the whole Australian and New Zealand population, and in 2013–2014, 488 mL were consumed per capita. The variation in consumption between regions when standardised to overall Australian and New Zealand values was marked, with New Zealand consuming 18% less IV fluid, and Tasmania consuming 32% more during the same period. Similarly variable results were obtained from 2013–2014 data (Tables 2 and 3).

Regional differences in crystalloid consumption
The volume and composition of crystalloid solutions varied between regions in both periods. The regional standardised volume of crystalloids consumed per capita varied between 82% and 133% of overall Australian and New Zealand consumption in 2012–2013, and between 92% and 133% in 2013–2014 (Tables 2 and 3, Figure 2). The proportional use of crystalloid fluid types varied markedly between regions in both periods. The consumption of acetated solutions in New Zealand was 400% greater than their overall consumption across Australia and New Zealand in 2012–2013, but was 90% less in Tasmania, with a similar variation seen in 2013–2014. The ratio of unbalanced to


A. Total volume of crystalloid and colloid solutions. B. Total volume of acetated solutions, lactated salt solutions and 0.9% sodium chloride solutions. C. Total volume of 20% albumin solutions, 4% albumin solutions, 6% hydroxyethyl starch solutions, 10% pentastarch and 4% succinylated gelatin solutions.
Critical Care and Resuscitation • Volume 18 Number 2 • June 2016

Figure 2. Regional consumption of crystalloid solutions in Australia and New Zealand, by fluid type (estimated by sales per capita), 2012–2013 and 2013–2014

A. Saline = 0.9% sodium chloride solution. B. CSL = compound sodium lactate. C. Acetate = PlasmaLyte (proprietary acetated solution). D. U:B = ratio of unbalanced to balanced crystalloid solutions.

balanced crystalloid solutions consumed varied from 87% to 236% of the overall Australian and New Zealand values in 2012–2013, and from 71% to 179% of these values in 2013–2014.

Regional differences in colloid consumption
The volume and composition of colloid solutions varied markedly between regions in both periods. The regional standardised volume of colloids consumed per capita varied from 64% to 162% of overall Australian and New Zealand consumption in 2012–2013, with similar variations in 2013–2014 (Tables 2 and 3, Figure 3). The proportional use of differing colloid types varied markedly between regions over the two time periods. The consumption of starch solutions in New Zealand was 183% that of Australia and New Zealand overall in 2012–2013, and 345% that of Australia and New Zealand overall in 2013–2014. The ratio of natural colloid solutions (albumin) to synthetic colloid solutions (gelatins and starches) used varied from 25% to 806% of the standardised Australian and New Zealand values in 2012–2013, and from 28% to 675% of the 2013–2014 Australian and New Zealand values. Artificial colloid use was dominant in New Zealand, but albumin solutions appeared to be more popular across Australia. No starch was used in the Northern Territory in either period (Tables 2 and 3).
Temporal changes in overall fluid consumption

Across Australia and New Zealand between 2012–2013 and 2013–2014, there was an increase in IV fluid consumption of approximately 626 000 L, a gross increase of 5% but a statistically non-significant increase of only 3% in per-capita terms (Figure 4, Table 1, Table 4).

Temporal changes in crystalloid consumption

Although there was no statistically significant increase in the total volume of crystalloid sold per capita between the two periods, there was a significant increase in the consumption of lactated solutions (7%; \( P = 0.02 \)) and acetated solutions (24%; \( P = 0.02 \)) in Australia and New Zealand. This translated into a 9% decrease (\( P = 0.02 \)) in the ratio of unbalanced to balanced crystalloid solutions consumed between the two periods (Figure 4, Table 4).

Temporal changes in colloid consumption

Total colloid sales per hospital admission decreased by 12% between 2012–2013 and 2013–2014 (\( P = 0.02 \)). This was primarily driven by a huge reduction in the consumption of starch (Figure 4, Table 4).

Discussion

Key findings

Using regional and national fluid sales data as a surrogate measure of fluid consumption, we describe the first published estimate of IV fluid use at a national level, for two countries. We make several new and important observations.

First, we show that the consumption of crystalloids across Australia and New Zealand is orders of magnitude greater than the consumption of colloids. Second, patterns of fluid consumption in Australia and New Zealand are different from those in other countries, which may be due to differences in clinical practice, patient demographics, or healthcare systems.

Third, there is a trend towards increased use of acetated crystalloids and reduced use of balanced crystalloids, which may have implications for blood safety and patient outcomes. Further research is needed to understand the reasons behind these changes and their clinical implications.

Fourth, the reduction in colloid consumption is likely to have implications for the management of severely ill patients, particularly those requiring large volumes of fluid for resuscitation. This may require changes in clinical practice and the development of new colloid products.

Finally, the use of regional and national fluid sales data as a surrogate measure of fluid consumption highlights the potential of such data for future research and policy-making in critical care and resuscitation.
fluid consumption are highly variable across Australia and New Zealand, with different crystalloids and colloids being used in different proportions and different total volumes in different regions in an apparently chaotic fashion. Acetated solutions, albumin solutions and 6% HES solutions, in particular, show massive regional variations in consumption over the study periods. Third, the ratio of unbalanced to balanced crystalloid consumption is falling in every region, suggesting that there is a widespread increasing preference for such balanced solutions over saline. Fourth, we show significant reductions in the sale of colloid solutions over a 2-year period, and a two-thirds decrease in the consumption of starch solutions, a finding congruent with recent trials showing toxicity.

Study findings in context

To our knowledge, this is the first published description of fluid administration at a bi-national level across two entire health services. The National Health Service of the United Kingdom spends about £156 million on IV fluids each year,9 and the only previously published estimate of IV fluid sales in the medical literature10 suggests that the UK purchases 10 million litres of saline annually. In Australia and New Zealand, more than 13 million litres are purchased, despite having a combined population less than half the size, while the US purchases 200 million litres.10 We were unable to identify information in the medical literature about temporal trends in fluid sales or use at a national level in the US.

Our description of fluid consumption patterns shows significant regional variation in IV fluid use. Such an inconsistent approach to fluid use has been described tangentially in other contexts. In 1994, world consumption of colloid solutions was 48.33 million units. Of these, 31.4% were albumin solutions (37.7% in New Zealand and 71.6% in Australia in 2013–2014); 44.9% were dextrans and starches (35.7% in New Zealand and 3.1% in Australia).
Figure 3. Regional consumption of colloid solutions in Australia and New Zealand, by fluid type (estimated by sales per capita), 2012–2013 and 2013–2014


in Australia); 9.3% were gelatins (26.8% in New Zealand and 25.5% in Australia); and 4.9% were other solutions. By comparison, the UK over the same period consumed 1.54 million units of colloid, 68% of which were gelatins. An international cross-sectional study of fluid resuscitation in 391 intensive care units showed marked international variability in the types of fluid used in the acute care setting. Recent Australian and New Zealand studies of paediatric emergency physicians and adult emergency physicians and intensivists also confirm that this inconsistency is likely to exist at an individual, as well as a regional, level. There is a marked paucity of information on the preferences of prescribing specialists outside these areas, although similar variability is likely to be present on general adult medical and surgical wards. The use of balanced or buffered solutions is not new, but the administration of such quantities of salt had been of concern since the inception of IV fluid experimentation. Recent evidence has highlighted the potential adverse physiological, and possibly clinical, effects of excess sodium and chloride administration. The use of balanced solutions has been shown, on meta-analysis of small trials of surgical patients, to be safe and associated with an improved perioperative metabolic profile when compared with non-physiological solutions. To our knowledge, ours is the first high-level demonstration of a changing, widespread bi-national preference for balanced crystalloid fluids over saline, a finding that is consistent with recent reports of changing preferences for resuscitation fluids in ICUs in Australia and New Zealand.
Colloid solutions have been used in acute care for a century and there has long been controversy about their role. However, given the modern understanding of microvascular fluid dynamics, the intravascular persistence of colloids is likely to be limited. It is also possible that fluid resuscitation itself may disrupt the glycocalyx, further altering the transvascular equilibrium in states of acute illness.

Clinical evidence has shown that replacement of colloids with crystalloids occurs with a 1:1.3 ratio instead of the 1:3 ratio that has been postulated by advocates of the traditional Starling hypothesis.

We show that in Australia and New Zealand, the use of colloid solutions is falling, primarily due to decreased consumption of starch-containing fluids in response to large, randomised controlled trials conducted in Australia and New Zealand, and elsewhere, showing harm. For the first time, we show the effect of these studies in real terms across the entire health service as evidence of translation of research into widespread practice.

Study implications
Our findings imply that there are unexplained major regional practice variations in the use of fluids. Acetated solutions, albumin solutions, and 6% HES solutions, in particular, show massive regional variation in consumption over the periods of the study, with threefold differences within Australia and up to sixfold differences between Australia and New Zealand. This implies that regional factors overcome evidence-based considerations.

The ratio of unbalanced to balanced crystalloid use is falling in every region, which implies that there is a widespread shift away from saline use. This shift, involving millions of litres and probably thousands to millions of patient exposures, leads us to believe that large, double-blind, randomised controlled trials are needed to define whether such changes are justified. New physiological solutions are in development for use in humans, and these will require extensive testing before being introduced.

Finally, the significant reduction in the sale of artificial colloid solutions and the two-thirds decrease in the consumption of starch solutions show that clinicians do respond to high-quality evidence when present. These changes are also high-level, bi-national evidence of translation of research into practice. They also show the impact and value of the National Health and Medical Research Council-funded Crystalloid versus Hydroxyethyl Starch Trial (CHEST) in driving practice change, with the 20 000 L decrease in starch use leading to approximately $460 000 in annual savings in health care expenditure in Australia alone.
Table 4. Changes in fluid consumption in Australia and New Zealand between 2012–2013 and 2013–2014, by fluid type, estimated by sales per capita

<table>
<thead>
<tr>
<th>Region</th>
<th>Saline†</th>
<th>CSL Acetate§</th>
<th>U:§</th>
<th>Total crystalloids</th>
<th>20% albumin§</th>
<th>4% albumin**</th>
<th>Gelofusine‡</th>
<th>Starch‡‡</th>
<th>N:S§§</th>
<th>Total colloids</th>
<th>Total fluids</th>
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<tr>
<td>NZ</td>
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<td>-5.0%</td>
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<td>-15.7% +12.1%</td>
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<td>-1.7%</td>
<td>+1.2%</td>
<td>-8.9%</td>
<td>-67.4%</td>
<td>+49.0%***</td>
<td>-12.4%*** +3.1%</td>
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</tbody>
</table>

CSL = compound sodium lactate. NZ = New Zealand. ACT = Australian Capital Territory. NSW = New South Wales. VIC = Victoria. QLD = Queensland. WA = Western Australia. SA = South Australia. TAS = Tasmania. NT = Northern Territory. na = not applicable. * Australian, NZ, and Australian + NZ crystalloid values adjusted to account for national sales to veterinary agencies. † 0.9% sodium chloride solution. ‡ PlasmaLyte (proprietary acetated solution). § Ratio of unbalanced to balanced crystalloid solution consumption. ¶ 20% human albumin solution. ** 4% human albumin solution. †† 4% succinylated gelatin solution. ‡‡ 6% hydroxyethyl starch + 10% pentastarch. §§ Ratio of natural (albumin) to synthetic (gelatin and starch) colloid consumption. *** P < 0.05 for change over time, across NZ, ACT/NSW, VIC, QLD, WA, SA, TAS, NT.

Limitations

Ours was an ecological study using census and government data, so had the limitations associated with this study design. We were unable to identify from this ecological data where these fluids were used, and there is likely to be significant variation between the fluids consumed in operating theatres and those consumed on the ward or in the emergency department or ICU. We do not know the factors that might have influenced the purchasing of fluids at a regional or individual hospital level, and the complexities of health care procurement make controlling for such factors nearly impossible. However, such factors may include emerging evidence, staff preference, changes in pricing or marketing strategy, and local or national changes in policy.

Given that we used proprietary sales data as a surrogate for actual use, our results may not accurately reflect the administration of fluids. However, it is unlikely that significant quantities of fluid are purchased but not used, and this methodology is unlikely to introduce significant bias. By using a per-capita rather than a per-hospital admission approach to consumption, and by correcting for veterinary sales where we were able to, we aimed to limit additional bias.

Conclusions

Ours was the first study of IV fluid sales as a surrogate of consumption at a bi-national level across two entire health services. We found that use was highly variable in Australia and New Zealand, with different crystalloid and colloid solutions being used in different proportions and different total volumes in different regions in a seemingly chaotic fashion. We found major regional variations in consumption of acetated solutions, albumin solutions and 6% HES solutions in particular over the study period. A widespread increasing preference for balanced solutions over saline was suggested by the falling ratio of unbalanced to balanced crystalloid use. Finally, we showed significant reductions in the consumption of starch solutions, a finding that fits with recent concerns about its safety. Our findings provide an up-to-date, bi-national insight into this fundamental component of medical practice across health services; imply that there is a need for trials comparing balanced solutions with saline; and provide a benchmark for the assessment of translation of research into practice.

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Competing interests

The Avant Doctor in Training Research Scholarship Program funds Neil Glassford’s research salary. Rinaldo Bellomo has received
unrestricted research grants from Baxter Healthcare. Craig French is the current co-chair of the National Blood Authority (NBA) Working Group, Patient Blood Management Guidelines and a member of the Australian Red Cross Blood Service (ARCBS) Advisory Committee. Johan Mårtensson has received travel grants from Gambro/Baxter International. Glenn Eastwood has no competing interests to declare.

Author contributions
Data integrity and accuracy: Neil Glassford had full access to all data in the study and is responsible for integrity and accuracy of data and analysis. Concept and design: all authors. Data acquisition: Glassford, Bellomo and French. Data analysis and interpretation: all authors. Drafting of the manuscript: Glassford, Bellomo and Bailey. Critical revision of the manuscript: all authors. Statistical analysis: Glassford, Bellomo and Bailey. Funding: Glassford and Bellomo. Administrative, technical or material support: Glassford, Eastwood and Bellomo. Study supervision: Glassford and Bellomo.

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References
17 Lim CT, Dunlop M, Lim CS. Intravenous fluid prescribing practices by foundation year one doctors — a questionnaire study. JRSM Short Rep 2012; 3: 64.
19 Latta T. Malignant cholera: documents communicated by the Central Board of Health, London, relative to the treatment of...
22 Ringer S. Concerning the influence exerted by each of the constituents of the blood on the contraction of the ventricles. *J Physiol* 1882; 3: 380-93.
41 Guidet B, Martinet O, Boulain T, et al. Assessment of hemodynamic efficacy and safety of 6% hydroxyethylstarch 130/0.4 vs. 0.9% NaCl fluid replacement in patients with severe sepsis: the CRYSTMAS study. *Crit Care* 2012; 16: R94.