PICANet

PICANet:

A Decade of Data

Paediatric Intensive Care Audit Network

University of Leicester

UNIVERSITY OF LEEDS

KEY

A		Cambridge University Hospitals NHS Foundation Trust
B		Brighton & Sussex University Hospitals NHS Trust
C		Cardiff & Vale University Health Board
D		Central Manchester University Hospitals NHS Foundation Trust
E		Great Ormond Street Hospital for Children NHS Trust
	E1	PICU/NICU
	E2	CCCU
F		Guy's & St. Thomas' NHS Foundation Trust
G		Hull & East Yorkshire Hospitals NHS Trust
H		King's College Hospital NHS Trust
I		Leeds Teaching Hospitals NHS Trust
K		Newcastle upon Tyne Hospitals NHS Foundation Trust
	K1/K3	Great North Children's Hospital
	K2	Newcastle Freeman Hospital
		(In 2010 Newcastle General and Royal Victoria Infirmary PICUs merged within the Great North Children's Hospital)
L		University Hospital of North Staffordshire NHS Trust
M		Queens Medical Centre Nottingham University Hospitals NHS Trust
N		Oxford University Hospitals NHS Trust
O		Royal Brompton & Harefield NHS Foundation Trust
P		Royal Liverpool Children's NHS Trust
Q		Sheffield Children's NHS Foundation Trust
R		Southampton University Hospitals NHS Trust
S		South Tees Hospitals NHS Trust
T		St. George's Healthcare NHS Trust
U		Imperial College Healthcare NHS Trust (SMH)
V		Birmingham Children's Hospital NHS Trust
W		University Hospitals Bristol NHS Foundation Trust
X		University Hospitals of Leicester NHS Trust
	X1	Leicester Glenfield Hospital
	X2	Leicester Royal Infirmary
Y		NHS Lothian – University Hospitals Division
Z		Barts and the London NHS Trust
ZA		NHS Greater Glasgow and Clyde – Women and Children's Division
ZB		The Royal Group of Hospitals and Dental Hospitals HSS Trust
ZC		Our Lady's Hospital for Sick Children, Dublin
ZD		The Children's University Hospital, Dublin
ZE		Harley Street Clinic (non-NHS)
ZF		The Portland Hospital for Women and Children (non-NHS)

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Paediatric Intensive Care Audit Network: A Decade of Data (published September 2014): Universities of Leeds and Leicester.

Dr. Philip Holland

04/05/1948 - 20/06/2014

We would like to dedicate this report to Dr Philip Holland who sadly died on Friday 20th June 2014.

As secretary of PICS SG, Philip put a great deal of energy, enthusiasm and wisdom

into the early development of PICANet.

Our thoughts are with his family, friends and colleagues.

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FOR THE TABLES AND FIGURES AND APPENDICES TO THIS REPORT

PLEASE VISIT:

WWW.PICANet.ORG.UK

ISBN 978 0 85316 335 0

ACKNOWLEDGEMENTS

The ongoing success of this international clinical audit is dependent on the hard work and commitment of a large number of individuals working within the paediatric intensive care community. We are very grateful to all the audit clerks, secretaries, nurses and doctors who support and contribute to the Paediatric Intensive Care Audit Network (PICANet) from their own paediatric intensive care units (PICUs).

PICANet was established in collaboration with the Paediatric Intensive Care Society (PICS) and their active support continues to be a key component of our successful progress. The PICANet Steering Group (SG) has patient, academic, clinical, government and NHS members all of whom are thanked for their continuing assistance and advice. Members of the Clinical Advisory Group (CAG) provide a formal interface between PICANet and clinical care teams and their valuable support and contribution is gratefully acknowledged.

We are also grateful for the support and commitment given by members of the PIC Families Group.

PICANet has been awarded funding to 31st March 2016 from the National Clinical Audit & Patient Outcomes Programme, administered by the Healthcare Quality Improvement Partnership (HQIP); Welsh Health Specialised Services Committee; NHS Lothian/National Service Division NHS Scotland; the Royal Belfast Hospital for Sick Children; National Office of Clinical Audit Ireland (NOCA) and HCA International.

Foreword

"Better is possible. It does not take genius. It takes diligence. It takes moral clarity. It takes ingenuity. And above all, it takes a willingness to try."

- Atul Gawande, *Better: A Surgeon's Notes on Performance*

In 2013 I had the privilege of hearing Atul Gawande give a keynote lecture at the annual American Academy of Pediatrics Conference in Orlando entitled 'The Century of the System'. His thesis was that while the last two decades have borne witness to an explosion of new technologies resulting in such important innovations as gene therapy and minimally invasive surgical procedures, we have now passed the exponential part of the 'molecule research' curve. In the coming years, the biggest 'bang for buck' in terms of healthcare gains will come from how we organise, develop and run our health systems. Of course it goes without saying that we need to invest in both 'molecule' and 'health services' research, but the lesson is clear; all the high technology techniques in the world will be in vain if we lack the basic organisational principles to get the right patient to the right centre with the right staff, training and equipment.

As has been demonstrated so many times, progress in clinical care is often driven by high profile deaths or scandals, and such has been the case in paediatric intensive care. It took the death of a 10-year old boy in 1995, who was failed by poorly organised services, to start a six year journey which culminated in a national PIC database and in 2001 the establishment of PICANet (see p.14). Since then the NHS has been in an almost continuous state of reorganisation, during which numerous structures and organisations have come and gone, and yet PICANet has survived and extended its reach. Despite the fact that our health systems across the four nations of the UK have become more autonomous and diverse, over the last decade data collection has expanded from England and Wales to include Scotland, Northern Ireland, the Republic of Ireland and importantly also the private sector.

Dr Hilary Cass

President,
Royal College of Paediatrics and Child Health

The endurance and cohesion of PICANet is testimony to the commitment of the clinicians, academics and patients who have supported it, and the value of the data it has produced. The report of the Children's and Young People's Health Outcomes Forum (2012) made the point that 'turning information into knowledge and evidence, together with research, is central to the drive for better outcomes'. Or put much more simply by one of the young people contributing to the report; 'if we count, count us'.

The good news story within this report - that in-PICU mortality is running at an all time low - means that it is incumbent on the rest of the child health system to ensure that routine health datasets are adequately linked to PICU datasets to enable more granular analysis of post-PICU morbidity outcomes. There is also more work to do on a variety of fronts, including setting standards for readmission rates, and understanding variations in interventions in different countries and regions. However, at a time when transparency and accountability could not be more important within the NHS, PICANet data continues to provide both encouragement and challenge to the intensive care community, and reassurance to the public. It represents a triumph of collaboration, and evidence that despite the fact that many aspects of the health service are devolved or fragmented, a vision of strategic joint working is still a strong motivational driver for all those committed to the highest standards of intensive care for children.

Executive Summary

In this report we have produced the standard analysis of data from the three year rolling period, 2011-2013 as well as longer term trends for selected topics over the period 2004-2013.

2011-2013

For 2011-2013 we present information on 58,951 paediatric intensive care admissions (aged under 16 years) and 1,392 admissions 16 years and over to 30 NHS trusts and Health Organisations and two non NHS paediatric intensive care units in the UK and Ireland.

Admission numbers have increased by 4% between 2011 and 2013.

Deaths on paediatric intensive care units are very rare: over 96% of children were discharged alive in 2011-2013. Crude mortality was at an all-time low of 3.7% in 2013, down 0.1 percentage points on 2012. Risk-adjusted performance of all participating health organisations fell within acceptable limits in each individual year and aggregated across the three year period.

Two thirds (67%) of admissions received invasive ventilation. This varied from 18% to 90% of patients by NHS Trust in 2013. Invasive ventilation rates continue to show variation by geographical region reflecting the different patient case-mix admitted to individual PICUs.

Over 367,000 bed days were delivered between 2011 and 2013. The year on year increase appears to reflect increased activity in some units. Just under one third of patients have a length of stay of less than 24 hours and a further third stay between one and three days. Nearly eighteen percent of patients remain on the same PICU for seven or more days.

Critical incidents were reported in 11.1% transport events in 2012 and 7.1% in 2013: about one third of these incidents were related to equipment problems.

There are still no established standards for emergency readmissions in paediatric intensive care. We report an average emergency readmission rate (defined as readmission to the same unit within 48 hours) of 1.7%, varying between 0% and 3.8% across all units in the three years 2011-2013. There is a suggestion that the three PICUs with the largest number of admissions have a slightly higher readmission rate.

Nursing establishment levels met the current PICS standard (7.01 whole time equivalent (WTE) nurses per critical care bed) in only 5 (15%) PICUs in 2013. However data collected about actual levels of nurses present at midday and midnight on a weekday and weekend during a specified week in November indicated that 68% of units at midday on a Wednesday and 74% at midnight on a Sunday met this PICS standard. For many units additional agency/bank nursing staff support the nursing roster on a shift basis to address the issue of staff shortfalls.

2004-2013

There has been an overall increase of 15% in admissions in England and Wales from 13,982 in 2004 to 16,100 in 2013. We believe most of this increase is due to an increasing birth rate, more children in the population of South Asian origin who have a higher rate of PICU admission and increasing numbers of children living with long term, life limiting conditions.

The proportion of admissions to PICUs requiring invasive ventilation varies widely between countries of residence from 43.0% in Scotland to 86.3% in Wales in 2013. Non-Invasive ventilation rates were lower and showed less variation, ranging from 13.2% of admissions in Northern Ireland to 23.9% in England.

The percentage of children receiving both invasive and non-invasive ventilation has increased steadily over the years from 8.6% to 16.8%

Median duration of ventilator support was similar over the decade at around 3 days for invasive and 2 days for non-invasive ventilation. Prolonged mechanical ventilation (defined as requiring invasive ventilation for >21 days) was required in approximately 3% of admissions for those children resident in England and Wales. Similarly there has been no change in the median distance travelled for PIC in England or Wales.

In 2004, 0.99% of all children from England and Wales admitted to PICU received Extra Corporeal Membrane Oxygenation (ECMO) compared to 1.23% in 2013. This increase appeared to be mainly in children in the youngest age group (<1 year old), who also had the highest percentage of children receiving ECMO increasing from 1.5% to 2.0% over the decade.

In 2013 the percentage of admissions where Renal Replacement Therapy was required varied from 2.1% in those resident in Northern Ireland to 3.7% in England. In England and Wales there was a annual increase of 0.1 percentage points in renal support over the ten year period.

There was a 35.7% (520 nurses) increase in the number of WTE clinically qualified nursing staff employed to provide patient care in the decade from 2004 to 2013 and a 40.1% (n=88) increase in the number of PIC beds. This equates to a small reduction in the ratio of WTE clinically qualified nurses to the number of beds in England and Wales. Nurse staffing levels have fluctuated over time reflecting both the turnover of staff and possible difficulties in the recruitment of paediatric intensive care nurses, both in terms of numbers, knowledge and skills.

Ranking and league tables based on Standardised Mortality Rates (SMR) alone are not a good method of assessing variation in institutional performance: over the period 2004-2013 the rank of most PICUs based on their SMR varied each year giving little meaningful information about underlying performance.

Recommendations

- The long term increase in demand for paediatric intensive care driven by increased birth rates and improved survival should be addressed not only with additional bed capacity but adequate staffing levels in accordance with professional standards.
- A standard for emergency readmission rates should be established to enable effective monitoring of this key quality indicator using PICANet data.
- As in-PICU mortality is running at an all time low and becomes less sensitive as a performance indicator, it is important to monitor mortality and morbidity post-PICU discharge by data linkage to routine health datasets held by the NHS Health and Social Care Information Centre.
- The increasing use of high flow nasal cannula therapy should be monitored and its effectiveness assessed in the PICU setting.

Lay Summary

As a lay representative of the PICs families group I feel privileged to be asked to contribute to this report. Whilst some of the data is not within my area of professional understanding, I have identified a number of areas which resonate deeply with me as a parent. These are around supporting PICU staff, improvements in treatment and deepening support for families.

PICANet works closely with the teams of doctors and nurses who care for children in Paediatric Intensive Care Units. PICANet established a PIC families group and have reviewed the facilities and information available to families of children admitted to PICU. As one of the lay representatives of the PIC families group, I am cognisant of a desire from PICANet to gain additional parental engagement and the group has highlighted a request for further learning on social media which may extend PIC families group's ability to widen its engagement with the families of patients who have experienced PIC. The desire to receive feedback from families strikes me as core to the PIC families group and PICANet shared aim, which is to reflect on the numerous areas in which PICUs care for their patients and to constantly evaluate, feedback and assess best practice.

As a lay representative, I am able to note the increased pressure on PIC services over the past decade and correlate that data with an increased birth rate in the general population. The data provided, and the history of the PIC service itself, highlights the on-going need to map out and strategically plan for the increased development of PICUs throughout the country. The data is further substantiated in the report as it lays out the vital need to ensure that levels of recruitment and retention of nursing staff are equally well planned.

The recruitment and retention of ITU nursing staff offers a snapshot which must be considered in tandem with the increasing pressure for PIC beds. The need for qualified staff, with appropriate skills and aptitude, is essential to meet the high levels of staff required to care for PICU patients. Nursing staff are highly valuable and through my experiences as a parent of a child in PICU, the interaction with nursing staff gave me insight into how my daughter was coping on a

Shelley Marsh

Lay Representative,
PICS Families Group

day-to-day basis. The pressure on PICU staff is tremendous and it was gratifying to read about work that is being undertaken to support nursing staff in preventing burnout, along with maintaining and further developing staff training needs. PICU staff turnover has also received attention, which is essential to offering appropriate support for nursing staff in ITU.

There has been investment in senior nursing leadership over the past decade and yet the majority of units have not been able to reach the PICS national standard for nursing staff during that time period. It is indeed quite remarkable that PICU mortality has improved with nursing staff being so stretched. Whilst there may be a number of complex answers to these issues, credit must be given to the nurses who go well beyond the call of duty to care for their PICU patients. However, it is vital that the reliance on the good will of nursing staff cannot be taken for granted in the medium and longer term, since this will ultimately increase pressure on ITUs as resulting job dissatisfaction and increasing pressure on nurses will ultimately have a negative impact upon the entire field.

Specific research into the changes over the last decade in ventilation support in PICU offers an opportunity for medical colleagues to take a step back and review findings over a ten year period. It is evident to the lay reader that whilst there have been significant changes in elements of PICU treatment provision over the last decade some types of provision remain relatively static. There is a need for further research in some areas and it is helpful to have PICANet continue to provide data to both understand current practice and outcomes and to be a key source of information for developing research proposals.

Through on-going research and analysis, PICANet ensures the quality of care patients receive remains high. The PIC families group meetings also provide a forum for professionals to discuss ways of approaching patients, parents and staff with an aim to gaining maximum data whilst also giving great consideration to approaching families with sensitivity and discretion. I would like to commend the work that has been done in ensuring that families are approached at a time which feels least intrusive, but also facilitates essential data gathering.

When my younger daughter spent considerable time in four PIC/NIC units, I was struck by the differences in professional interactions with my family and I was able to recognise the overwhelming feeling of helplessness that many families feel when their child is critically ill. My elder daughter was 8 years old at the time of her sibling's premature birth and subsequent admissions into ITU. The bewilderment that my elder daughter experienced, and the lack of information which was presented in a child-friendly manner, was the subject of discussion at one PIC families group meeting. At the meeting, medical professionals discussed how best to manage the number of siblings who would be on PICUs throughout the country over the long summer break, experiencing similar confusion to that I had seen in my own daughter's experience whilst siblings were treated in PICU. As a result of these discussions I wrote and illustrated a short story which I hope will be shared through PICANet with patients' siblings which is available from the PICANet website: www.picanet.org.uk.

I had sought a way to engage with health care professionals since I perceived that my parental experiences of PICU and NICU would be helpful. My involvement with PICANet has been meaningful and I hope adds value to the meetings I am able to attend. It is a privilege to be a parental representative, working with highly dedicated medical professionals. A decade of data is being well utilised professionally and families are in a position to access further knowledge, information and support.

This report assesses a decade of data collected and analysed by PICANet. It has been a decade since my first interaction with PICUs and during that time my own child has developed into a bright and sunny 10 year old girl. The hard work of health care professionals, research, data analysis and subsequent learning have played a huge part in enabling my daughter to live the life that she is living. I know that I write on behalf of countless PIC parents whose children have gone on to recover and even thrive, and we are grateful that PICANet continues to work tirelessly to strive for further improvements in caring for children.

BACKGROUND & INTRODUCTION

The origins of PICANet

The death of a ten-year old child called Nicholas Geldard in 1995, the subject of an enquiry commissioned by the North West Regional Health Authority [1], acted as a catalyst for reviewing the way in which critically ill children were treated in the NHS. Nicholas Geldard died in a paediatric intensive care unit (PICU) following a spontaneous cerebral haemorrhage. He had previously been transferred from the admitting hospital to another hospital for a CT scan and then to the PICU in which he died. Unfortunately there was no local PICU bed (in Manchester) and he was transferred to the PICU in Leeds, necessitating an extended transfer time. There was an outcry at the time of Nicholas Geldard's death, and also following publication of the Regional Health Authority's enquiry (the then MP for Peckham, Ms Harriet Harman described it as *'…hard to find words to express the sense of outrage and betrayal that everyone must feel on hearing how 10-year-old Nicholas Geldard died.'* [2]).

In response to this report, the Secretary of State for health commissioned a report on how paediatric intensive care services had been developed and run within the NHS and how they should be planned for the future. The Department of Health (DH) set up a national coordinating group in June 1996 to develop a policy framework for PIC and report to the Chief Executive of the NHS the following year. The resultant report, *Paediatric Intensive Care: A Framework for the Future*, published in July 1997, set out a strategy for developing and unifying the service for critically ill children in each area of the country and made a number of recommendations based on the evidence available.

In particular, the report identified a number of key features of the PIC service at that time:

1) The service had developed in an *ad hoc*, unplanned way over the preceding 20 years.
2) PIC was provided in a range of settings including designated PICUs, adult intensive care units, general children's wards, single speciality hospitals and special care baby units.
3) There was a lack of evidence on standards that provide the best outcomes for critically ill children.
4) There were 223 designated PIC beds, many of which were in units with less than 3 beds.
5) Half of the children treated were under 2 years of age.
6) There were few specialised retrieval services for critically ill children (many of which were not staffed on a 24-hour basis).
7) There were not enough clinicians and nurses with PIC skills.

(National Coordinating Group on Paediatric Intensive Care, 1997)[3].

In an editorial discussing the implications of the policy framework outlined in this document, Jane Ratcliffe, then a consultant in PIC at the Royal Liverpool Children's Hospital NHS Trust, Alder Hey commented: *Quality of paediatric intensive care includes effectiveness and appropriateness of treatment within a child and family orientated environment. There is no validated paediatric scoring system for severity of illness in the United Kingdom and no information about long term outcome. We urgently need such studies so that further* *reorganisation of the paediatric intensive care service is informed by research and audit.* [4]

Due in part to this report and the subsequent dialogue between the clinical community, the NHS and the DH, the concept of a national database of PIC was developed. The Paediatric Intensive Care Society Study Group (PICS SG), a sub-group of the Paediatric Intensive Care Society (PICS), the professional body of clinicians and nurses working in PIC, commenced discussions with the DH with a view to developing and maintaining a clinical database. The aims of the database were to: identify best clinical practice; monitor supply, demand and outcomes; facilitate healthcare planning and quantify resource requirements; permit the study of the epidemiology of critical illness in children; plan for future practice, research and interventions and to accumulate baseline data for randomised controlled trials (RCTs). The initial impetus for this project and subsequent support was provided by PICS SG. The then Chair, Mark Darowski, and Secretary, Philip Holland, from the Leeds Teaching Hospitals Trust were instrumental in this process.

At this point, the DH decided that the development and day-to-day running of the national database should be put out to competitive tender. A collaborative tender submitted by the Universities of Leeds, Leicester and Sheffield was successful and the Paediatric Intensive Care Audit Network (PICANet) was established in 2001.

Since those early days, PICANet has grown in scope and complexity: from November 2002, all NHS PICUs within England and Wales outside the Pan Thames region have contributed data on all admissions to their units. The Pan Thames units began data collection in March 2003, the PICU at the Royal Hospital for Sick Children, Edinburgh in December 2004. The Royal Hospital for Sick Children, Glasgow in March 2007 and The Royal Belfast Hospital for Sick Children in April 2008. Our Lady's Children's Hospital, Crumlin and the Children's University Hospital, Temple Street, both based in Dublin, have submitted anonymised data to PICANet from 2010. The Harley Street Clinic PICU started contributing data in September 2010, and the PICU at the Portland Hospital from October 2013, allowing both these non-NHS units to compare their performance against the national benchmark provided by PICANet. A full list of participating PICUs can be found in Appendix A of the online annual report section of the PICANet website.

A decade of data

Over the last 13 years PICANet has become established as the definitive source of data on paediatric intensive care activity in the UK and Ireland. PICANet data has been used to plan PIC services, model demand and to assess interventions and outcomes. We have provided baseline data for the two largest clinical trials in paediatric intensive care (CHiP and CATCH). PICANet data has also been used as the gold standard in evaluating data returned by NHS Trusts to the NHS HSCIC Casemix Service for the development of the Paediatric Critical Care Minimum Dataset.

Since PICANet was established we have seen the development of specialist regional transport services and an expansion of bed numbers in the context of an increasing population. We have observed falling mortality and consistent quality of care delivered out of hours [5]. With reference to the original findings of the National Coordinating Group on Paediatric Intensive Care, we have charted the growth of paediatric intensive care as a distinct clinical speciality carried out in a safe, dedicated environment with professional standards against which PICANet can measure performance.

In this report we have produced six chapters in which we examine trends for the 10 years of data submitted between 2004 and 2013. Each chapter has involved clinical oversight from a member of the PIC community and we are very grateful for their help in interpretation of the analyses presented.

Governance

PICANet continues to receive support from the NHS Health Research Authority Confidentiality Advisory Group (formerly the NIGB) to collect personally identifiable data on infants and children admitted to paediatric intensive care without consent

(http://www.hra.nhs.uk/documents/2013/11/piag-register-2.xls).

Ethics approval has been granted by the Trent Medical Research Ethics Committee, ref. 05/MRE04/17 +5.

PICANet receives support and advice from a Clinical Advisory Group (CAG) drawing on the expertise of doctors and nurses working within the speciality and a Steering Group (SG), whose membership includes Health Services Researchers, representatives from the Royal Colleges of Paediatrics and Child Health, Nursing and Anaesthetics, a lay member and commissioners. We also have a PIC Families Group to consider the impact of admission to intensive care on children and their families. Appendices B, C and D provide a full list of CAG, SG and PIC Families group members. Additional support from the clinical community is provided through the Paediatric Intensive Care Society.

Data and information requests

Requests for data and information have increased year on year since 2011 when there were 50 requests to 85 requests in 2013. All data and information requests are sent to Dr Mark Peters as Chair of PICS SG and the full membership of the PICANet Clinical Advisory Group for comment and advice on acceptability. They are also reviewed by the PICANet Steering Group and published on the PICANet website (www.picanet.org.uk). The close scrutiny involved in the additional use of PICANet data drives improvements in quality and for this reason we encourage data requests despite the added burden this places on the team.

Anyone who requests and receives data or information from PICANet must provide a written response on how the data has been used and must acknowledge PICANet and our primary funder, HQIP, in all presentations and reports. In the case of publication, it is expected that a member of the PICANet team will be included as an author and therefore will have reviewed the manuscript and contributed to the analysis and interpretation. Our document, *Data and information requests: policy on use of data, publication and authorship. Version 1.2.1 February 2011*, available from www.picanet.org.uk contains more details. We are working with HQIP to align the use of PICANet data with the rest of the National Clinical Audit Programme. This will mean that all applicants will need to complete additional forms for HQIP, who have contractual rights over the PICANet data. These processes have not been confirmed at the time of going to press.

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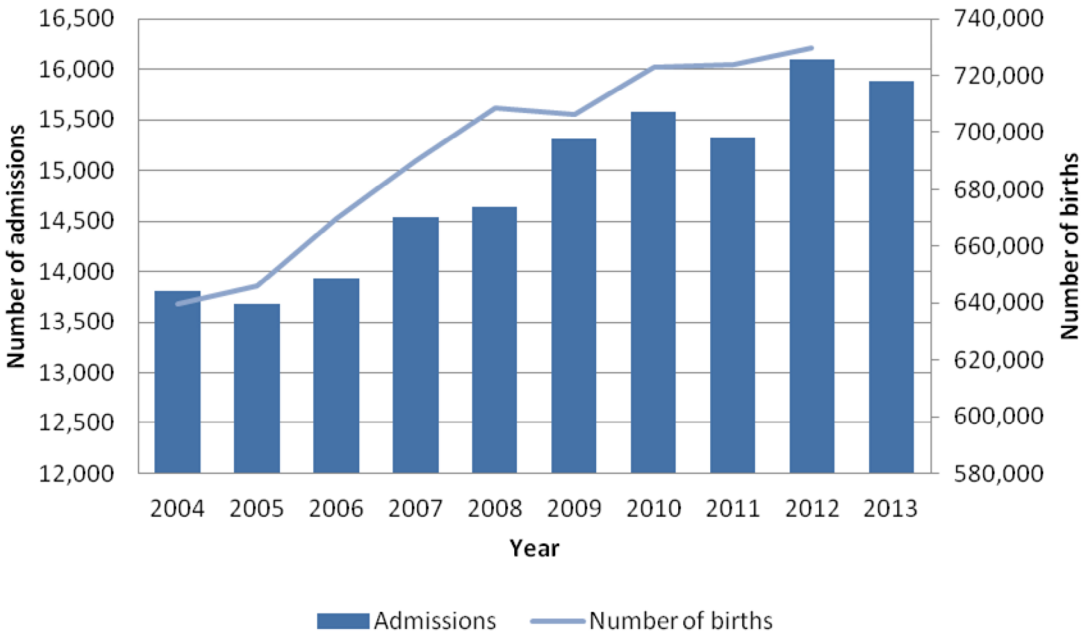
Ten years of increasing demand for Paediatric Intensive Care

Clinical review by Dr Peter Davis
Consultant in Paediatric Intensive Care, Bristol Royal Hospital for Children

Background

From 2004 to 2013 148,783 admissions for children up to 16 years of age have been submitted to PICANet. The first ten years of PICANet have seen an annual increase in the number of admissions recorded. This was expected as over the years PICANet has expanded from coverage of NHS units in England and Wales alone to include the whole of Scotland, Northern Ireland, and the Republic of Ireland as well as private sector units. However there has also been an independent increase in the number of admissions recorded annually in the original countries (England and Wales) between 2004 and 2013. Figure 1 below shows the increase in the numbers of PICU admissions of 0-15 year old children in England and Wales. Over the 10 year period there has been a 15% increase in PICU admissions.

Figure 1. The number of admissions each year to PICUs in England and Wales between 2004 and 2013



In this chapter we explore two of the reasons for this increase in PIC admissions during this period and estimate the size of their effect; firstly the rise in the birth rate in England and Wales during the last decade and secondly the increase in the number of children in the population of South Asian ethnicity who have previously been found to be at higher risk of experiencing a PICU admission [1, 2]. We estimate the effect of changes in the demography of the paediatric population to see whether this alone explains the increase in admission numbers and discuss other potential factors which may also have led to increasing numbers of PIC admissions.

Figure 1 shows the total number of births each year since 2004 in England and Wales, an increase of approximately 10,000 births per year [1]. Several reasons have been suggested for this increase including an increasing total fertility rate, women who previously were delaying starting a family now having children at an older age and other factors relating to immigration, economic and policy related changes [3].

One way to explore the effect of a changing population structure is to use predictions from population data to estimate how many children of each age group were in the population within each year. Here we present an analysis using the "Understanding Populations Trends and Processes" model (UPTAP) which creates an estimate from available UK Census data of how many children by age group were alive each year including estimates for two main ethnic groups: South Asian and non South Asian [4]. These provide the denominators to predict how many children require paediatric intensive care each year and can be accessed via the ETHPOP project website [5].

Findings

The data presented in table 1 shows that whilst the overall number admissions at each age group has increased significantly the rate of admission has not changed much for any of the age groups although there is some evidence of a higher proportional increase in 6-15 year olds.

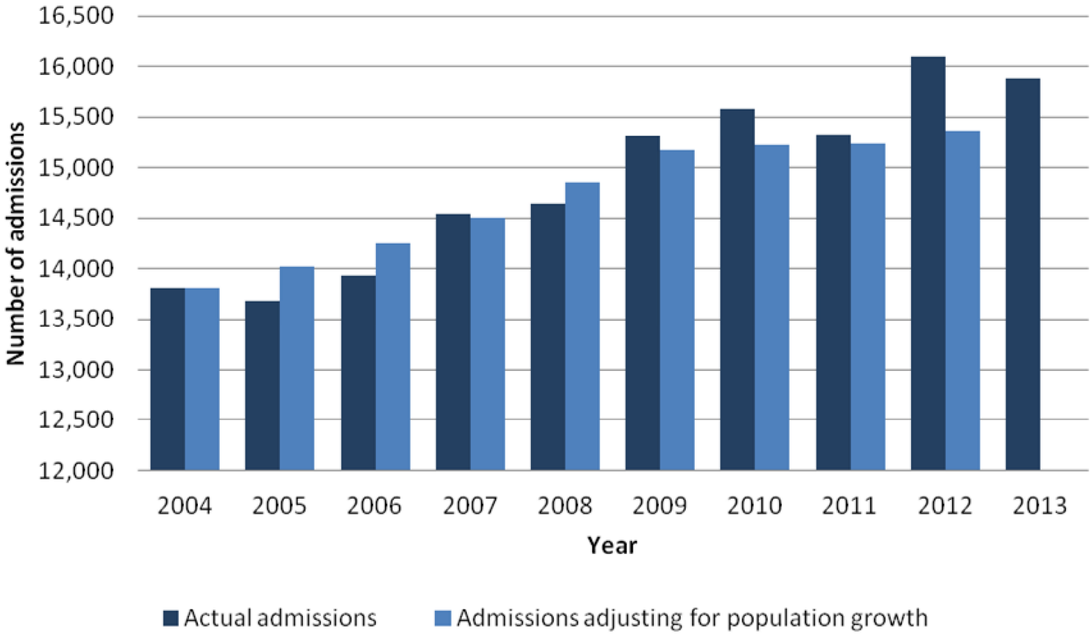
Table 1. Estimates of populations from the model, number of admissions and admission rates for 2004 to 2012 for England and Wales by age and ethnicity*

	Population			Admissions			Admissions per 1,000		
Age (years)	0	1-5	6-15	0	1-5	6-15	0	1-5	6-15
Overall									
2004	632,206	3,006,654	6,670,251	6,699	3,846	3,262	10.60	1.28	0.49
2005	648,425	3,017,964	6,623,651	6,561	3,845	3,271	10.12	1.27	0.49
2006	666,751	3,058,057	6,537,620	6,697	3,925	3,308	10.04	1.28	0.51
2007	685,669	3,137,521	6,418,254	6,928	4,163	3,442	10.10	1.33	0.54
2008	711,496	3,236,092	6,309,237	6,923	4,207	3,509	9.73	1.30	0.56
2009	733,018	3,334,161	6,235,810	7,336	4,373	3,600	10.01	1.31	0.58
2010	726,401	3,432,524	6,193,052	7,563	4,593	3,423	10.41	1.34	0.55
2011	722,457	3,507,120	6,181,706	7,471	4,464	3,395	10.34	1.27	0.55
2012	729,674	3,570,594	6,194,332	7,888	4,644	3,568	10.81	1.30	0.58
South Asian									
2004	48,263	214,634	407,164	787	501	306	16.31	2.33	0.75
2005	50,676	220,986	414,536	840	517	306	16.58	2.34	0.74
2006	53,568	228,954	418,574	872	572	339	16.28	2.50	0.81
2007	56,801	240,498	419,783	910	639	387	16.02	2.66	0.92
2008	60,168	254,752	421,538	937	649	405	15.57	2.55	0.96
2009	62,797	269,665	427,582	1002	707	413	15.96	2.62	0.97
2010	62,691	284,088	436,571	1088	751	450	17.35	2.64	1.03
2011	62,658	295,599	446,350	994	702	462	15.86	2.37	1.04
2012	66,962	304,766	457,569	1115	642	494	16.65	2.11	1.08
Non-South Asian									
2004	583,943	2,792,020	6,263,086	5,912	3,345	2,956	10.12	1.20	0.45
2005	597,749	2,796,978	6,209,115	5,721	3,328	2,965	9.57	1.19	0.45
2006	613,183	2,829,103	6,119,045	5,825	3,353	2,969	9.50	1.19	0.47
2007	628,869	2,897,023	5,998,471	6,018	3,524	3,055	9.57	1.22	0.48
2008	651,328	2,981,340	5,887,698	5,986	3,558	3,104	9.19	1.19	0.50
2009	670,220	3,064,496	5,808,228	6,334	3,666	3,187	9.45	1.20	0.52
2010	663,711	3,148,437	5,756,481	6,475	3,842	2,973	9.76	1.22	0.49
2011	659,799	3,211,522	5,735,355	6,477	3,762	2,933	9.82	1.17	0.49
2012	662,712	3,265,828	5,736,763	6,773	4,002	3,074	10.22	1.23	0.52

* Where ETHPOP did not have a Figure for the population the cohort was considered to be constant (i.e. 2009 age 0 is equal to 2011 age 2). For 2012 age 0 the ONS births were used but no data were available to estimate the populations for 2013.

Using the admission rates at each age in 2004 and the population figures at each age within each year we can predict how many admissions would have been expected if the admission rate had remained constant (figure 2). In most years the number of admissions is similar to what might be expected with a static admission rate although more recently (2009 onwards) admissions are consistently higher than would be expected if the change in population size alone was affecting admission rates.

Figure 2. Actual admission rates vs. predicted number of admissions based on the change in population size and structure



To estimate the additional change in number of admissions due to changes in the percentage of children of South Asian ethnicity the population estimates from ETHPOP were used. To define ethnicity in the PICANet data-set of admissions any child who had been entered as *Indian*, *Pakistani*, *Bangladeshi* or *Any other Asian Background* was also categorised as South Asian. Further South Asian children were identified by using two versions of name analysis software; Nam Pehchan [6] and SANGRA [7]. Any child with a matching level of three or more in Nam Pehchan and the output from SANGRA was classified as South Asian.

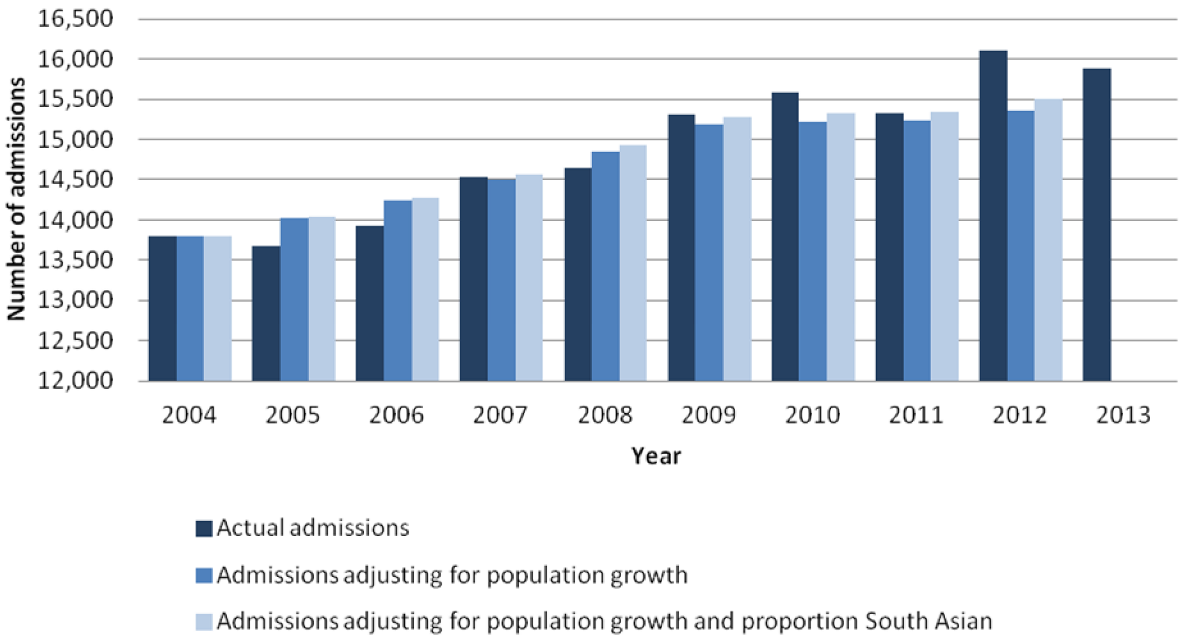
As can be seen in Table 1, South Asian children have higher admission rates, and the proportion of the population who are of South Asian ethnicity has increased over the last decade. Table 1 also shows that admission rates have increased in the South Asian population over the same period at a faster rate than for non-South Asian children for those aged 6-15 years. Figure 3 shows the additional adjustment for ethnicity alongside that for population differences alone.

The increased birth rate accounts for a large part of the increase in admissions. A further proportion can be explained by the increasing proportion of the population from South Asian ethnicity and their higher admission rate. However there is still an increase of about 4% in admissions that cannot be explained by these demographic factors.

Limitations and Uncertainties

The analysis has some possible limitations and uncertainties. Over this ten year period a number of changes in the threshold for admission to a PICU may have occurred (e.g. greater HDU provision) due to policy changes or availability of funded beds which are not directly related to the level of care children require but the location in which they are treated.

Figure 3. Actual admission rates vs. number of admissions predicted based on the change in population size, structure and ethnicity



The population estimates are based on a model which may under or over predict the true populations of children in each age group.

Defining the ethnicity of an individual is subjective and several methods can be used. It is unlikely that there is much consistency about how individuals record ethnicity in different units. Using a naming algorithm identifies more South Asian children, but will wrongly identify some children and will still be too conservative to identify all South Asian children; the method can also be subject to error as found in a previous analysis of PICANet data [2].

Discussion

Changes in population structure over the previous decade in the UK have led to an increase in PICU admissions; this illustrates how changing demography needs to be taken into account when planning future provision of intensive care. If birth rates remain at their current level or continue to increase so will the paediatric population and therefore the demand for PIC provision. This changing demography may also lead to variation in regional demand with some areas experiencing higher birth rates and therefore more admissions.

After adjustment for the changing demography, in terms of the birth rate and ethnicity, there was still a proportion of the increase in admissions which could not be explained. Other potential explanatory factors could include preterm children surviving to go on to have increased risk of critical illness and an increasing number of children living with life limiting conditions that may be more susceptible to infections or require major surgery followed by a period of intensive care support [8]. A programme of work is planned to investigate this issue further.

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CHANGES OVER THE LAST DECADE IN VENTILATOR SUPPORT IN PICU

Clinical review by Dr Kevin Morris
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Background

Over the last decade for every admission recorded as part of PICANet, data is provided on whether a child received invasive (IV) or non-invasive ventilation (NIV) or both during their stay. Changes in practice and available methods of ventilation have advanced over the last decade and this analysis explores how these changes may have affected the percentage of children receiving ventilatory support and the duration of use. Patient case-mix has also changed with the percentage of the paediatric population on long term ventilator support increasing in the UK [1,2]; this group of children frequently require long term PICU stays and tend to have higher hospital utilisation overall [3].

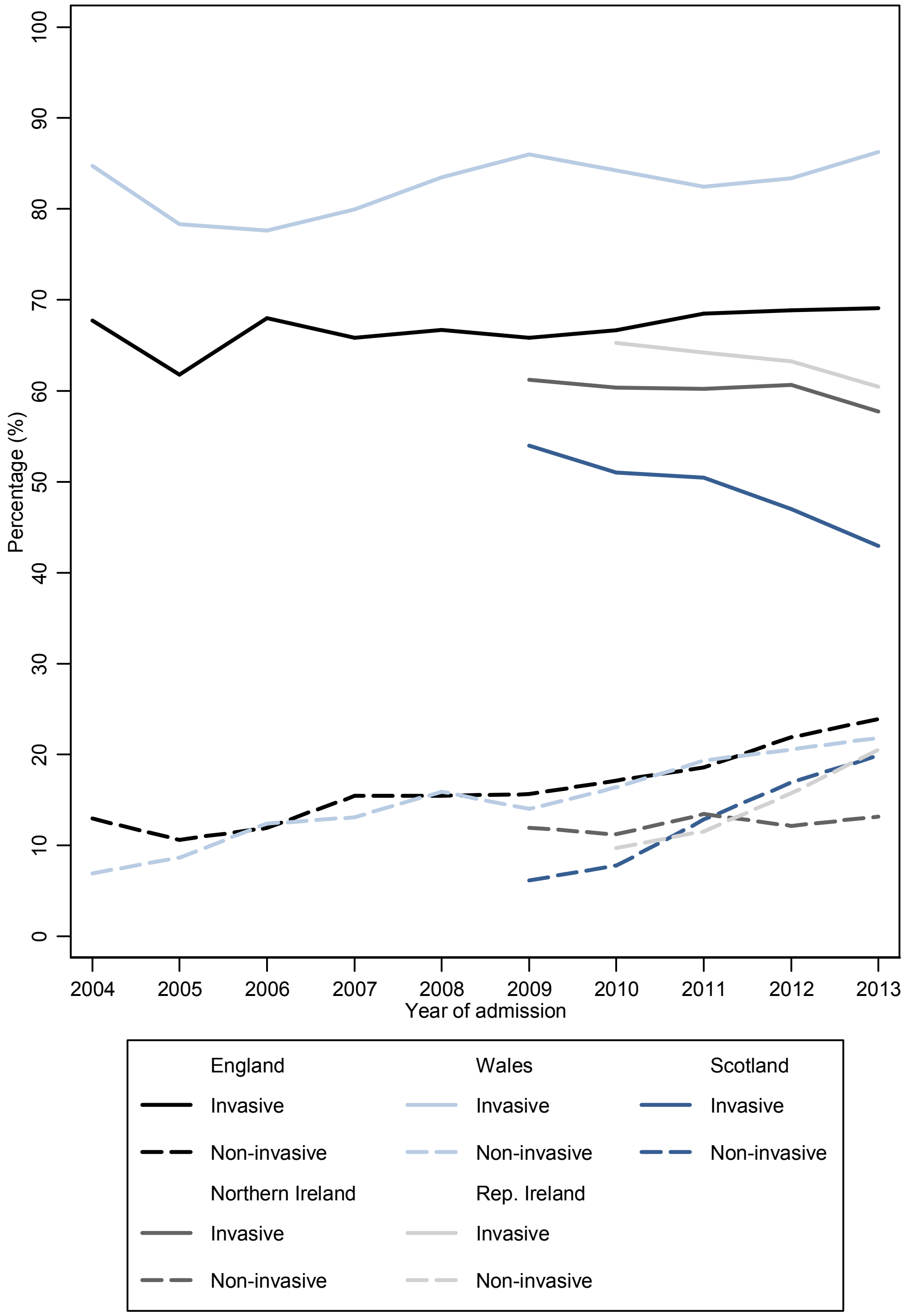
New methods of oxygen provision have been developed over this period such as 'high flow nasal cannula therapy' with uncertainty about its role in relation to NIV and continuing debate over its classification. PICANet guidance is that high flow nasal cannula therapy should not be classified as NIV but PICANet validation visits have highlighted discrepancies between units in how it is classified. An additional unique data field for 'high flow nasal cannula therapy' will help us to identify use moving forward and to audit the outcomes achieved.

Findings

Ventilation by type

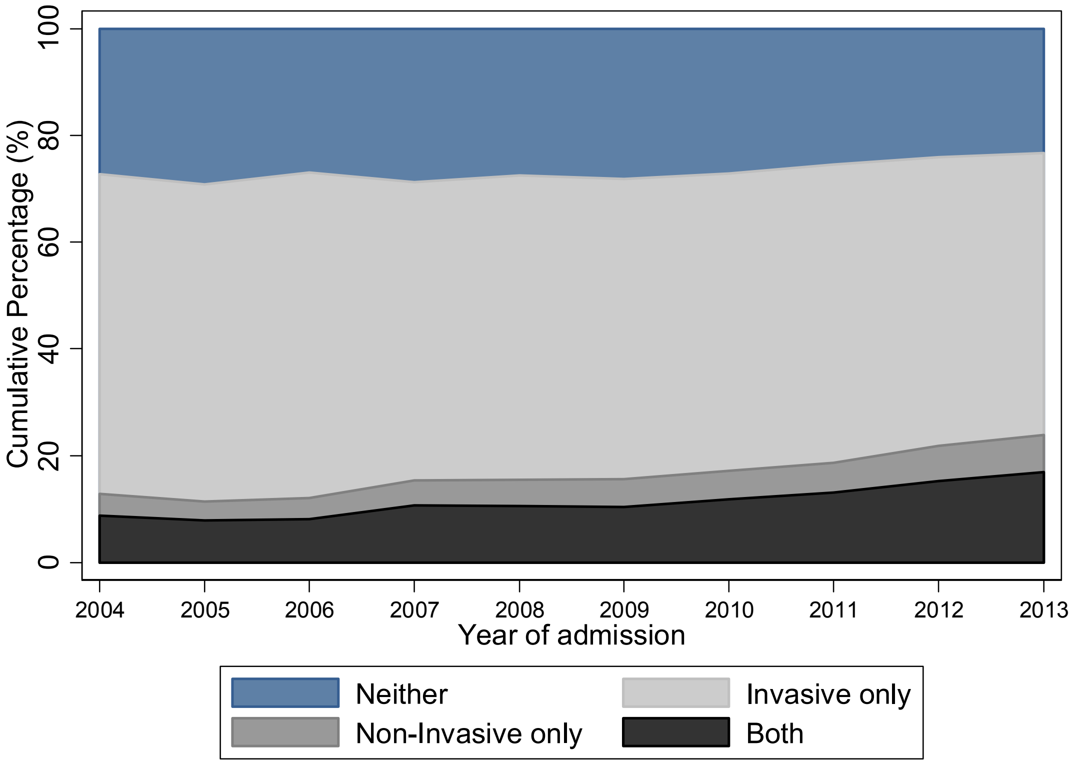
Ventilation type was based on intervention data completed for each patient concerning the interventions they received during their stay. Non-invasive ventilation was defined as the child receiving one or more day of non-invasive ventilatory support, entered as a summary field or if data were entered daily by the unit it was defined as 'non-invasive ventilatory support'. Invasive ventilation was either the summary intervention data supplied for that patients stay or if data were supplied daily it was defined as via endotracheal tube or tracheostomy, and included jet ventilation or oscillatory ventilation as well as conventional ventilation. The proportion of admissions to PICUs requiring IV varies widely depending on the country of residence from 43.0% in Scotland to 86.3% in Wales in the most recent reporting year, 2013. NIV was less common and showed less variation ranging from 13.2% of admissions for those resident in Northern Ireland to 23.9% in England. In some cases (15.8% in 2013) children received both invasive and non-invasive ventilation during their stay; those children are included in both the invasive and non-invasive ventilation percentages in Figure 1.

Figure 1. Percentage of admissions to PICUs where ventilation was administered by country of residence from 2004 to 2013



Exploring changes over time between 2003 and 2014 in both England and Wales, as these are the countries for which data has been collected over the full reporting period, children were classified as receiving one type of ventilation only, both types; neither type, or their ventilation status was unknown. The percentage of children receiving both invasive and non-invasive ventilation has increased steadily over the years from 8.6% to 16.8% (average increase of 0.96% per annum, p<0.001) as has the percentage of children receiving non-invasive only (average increase of 0.36% per annum, p<0.001) (Figure 2). Invasive only ventilation has remained relatively stable with a small drop in recent years (Table 1). Complementarily there has been a significant reduction in those receiving neither type of ventilation (average decrease of 0.40% per year, p=0.024).

Figure 2. Percentage of children admitted to PICU who are resident in England and Wales receiving one or both types of ventilation, 2004-2013*



* Those with unknown status not included in the graph

Table 1. Type of ventilation by year for children residing in England and Wales 2004-2013

Year	Total admissions	Both		Non-invasive only		Invasive only		Neither		Not known	
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
2004	13,684	1,183	(8.6)	555	(4.1)	8,179	(59.8)	3,699	(27.0)	68	(0.5)
2005	13,503	976	(7.2)	447	(3.3)	7,461	(55.3)	3,641	(27.0)	978	(7.2)
2006	13,818	1,114	(8.1)	537	(3.9)	8,339	(60.3)	3,691	(26.7)	137	(1.0)
2007	14,418	1,534	(10.6)	678	(4.7)	8,050	(55.8)	4,129	(28.6)	27	(0.2)
2008	14,583	1,531	(10.5)	727	(5.0)	8,306	(57.0)	4,000	(27.4)	19	(0.1)
2009	15,167	1,580	(10.4)	781	(5.1)	8,540	(56.3)	4,261	(28.1)	5	(0.0)
2010	15,485	1,818	(11.7)	832	(5.4)	8,614	(55.6)	4,174	(27.0)	47	(0.3)
2011	15,306	2,002	(13.1)	847	(5.5)	8,563	(55.9)	3,886	(25.4)	8	(0.1)
2012	16,114	2,451	(15.2)	1,068	(6.6)	8,733	(54.2)	3,862	(24.0)	0	(0.0)
2013	15,821	2,664	(16.8)	1,110	(7.0)	8,359	(52.8)	3,678	(23.2)	10	(0.1)

Length of ventilation

Table 2 provides details on the time per admission spent on ventilatory support by year for IV and NIV over the period 2004 to 2013 in England and Wales using a variety of parameters to indicate the skewed nature of this data. Median duration of ventilator support was similar across all years at around 3 days for invasive and 2 days for non-invasive ventilation. Prolonged mechanical ventilation defined as requiring invasive ventilation for >21 days [5] was required in approximately 3% of admissions over the ten year period for children residing in England and Wales.

Table 2. Summary on time spent on ventilator support per admission per type of ventilation 2004-2013 for children residing in England and Wales*

	Mean	SD	Min	Q1	Median	Q2	Max	% Prolonged
Invasive								
2004	5.2	10.9	<1	1	3	6	407	3.11
2005	5.1	12.1	<1	1	2	5	509	3.01
2006	4.9	10.4	1	1	2	5	381	2.55
2007	5.0	9.1	1	1	3	6	294	2.62
2008	5.3	10.8	1	2	3	6	293	2.79
2009	5.2	10.9	1	2	3	5	426	2.89
2010	5.4	11.4	1	2	3	6	383	3.04
2011	5.4	10.9	1	2	3	6	348	3.13
2012	5.7	13.4	1	2	3	6	647	3.19
2013$	5.6	11.4	1	2	3	6	287	3.41
Non-invasive								
2004	3.5	7.7	<1	1	2	3	182	-
2005	4.0	10.7	<1	1	2	4	250	-
2006	3.8	8.7	1	1	2	4	185	-
2007	3.6	7.1	<1	1	2	3	173	-
2008	3.6	5.8	1	1	2	4	100	-
2009	3.4	5.3	1	1	2	4	118	-
2010	3.8	7.6	1	1	2	4	223	-
2011	3.8	6.1	1	1	2	4	113	-
2012	4.3	8.2	1	1	2	4	202	-
2013$	4.1	6.6	1	1	2	4	129	-

* Children who received both types of ventilation would be counted to the number of days on each under each ventilation type – data are recorded as full days only so half a day on invasive and half a day on non-invasive would count as a day towards each.

$ Some children from 2013 with very long stays may not yet have been discharged as they may stay more than 12 months and so the maximum is likely to be an underestimate.

Ventilation by age

When using data for children residing in England and Wales across the whole decade the pattern was similar across age groups with no single age group driving the overall changes (Figure 3a, b). Invasive ventilation showed greater differences by age group with the highest percentage of children invasively ventilated in the under 1 year olds and the least in the 16+ years category (Figure 3a) these differences by age weren't as apparent in the non-invasive ventilation data (Figure 3b) (Note different scales for vertical axes).

Figure 3a. Percentage of admissions to PICUs where invasive ventilation was administered from 2004 to 2013 for children residing in England and Wales only by age

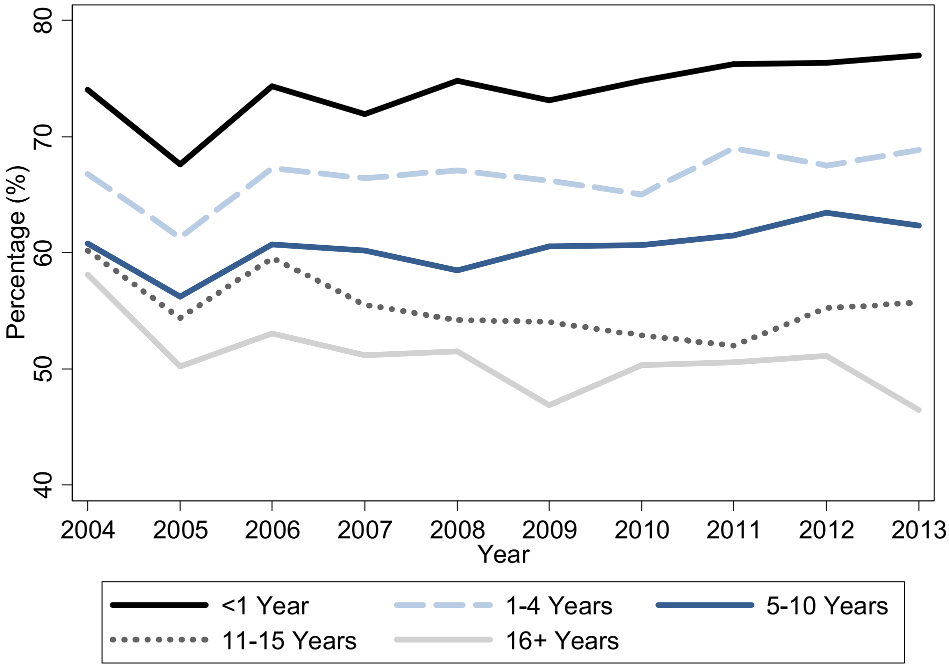
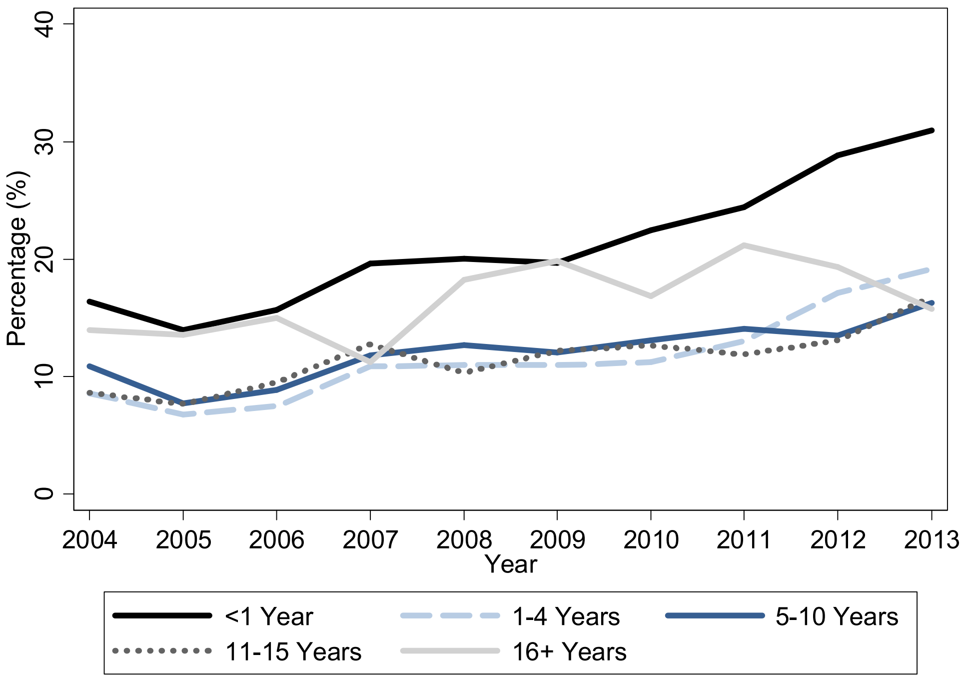
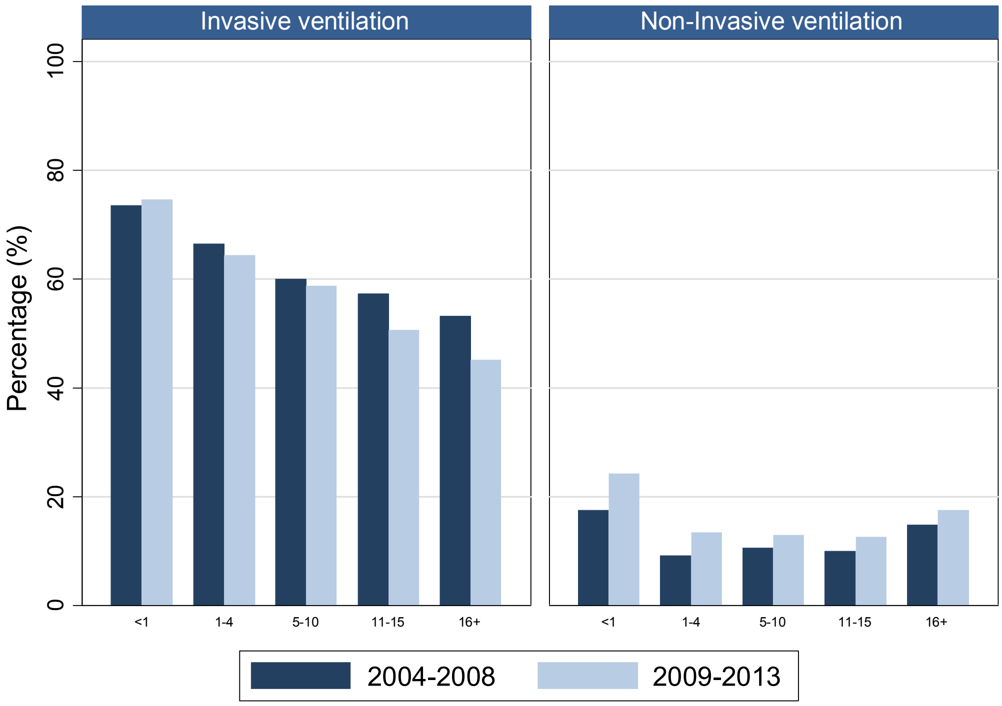


Figure 3b. Percentage of admissions to PICUs where non-invasive ventilation was administered from 2004 to 2013 for children residing in England and Wales only by age



Comparing patterns of ventilation across age groups over the ten years, invasive ventilation showed an inverse relationship to age: 77% of the youngest age group (<1yrs) declining to approximately half of those children admitted aged 16 years or more. The distribution for non-invasive ventilation rates was 'U' shaped with higher levels for the youngest and oldest admissions, 21% and 18% respectively, and lower rates for the remaining age groups. Levels of invasive ventilation increased between the two periods in the youngest age group (<1 yrs) from 79.9% in 2004 to 2008 to 85.0% in 2009 to 2013 whereas all other age groups showed a small decrease. An increased use of non-invasive ventilation occurred across all age groups between the two periods: 2004 to 2008 and 2009 to 2013 (Figure 4).

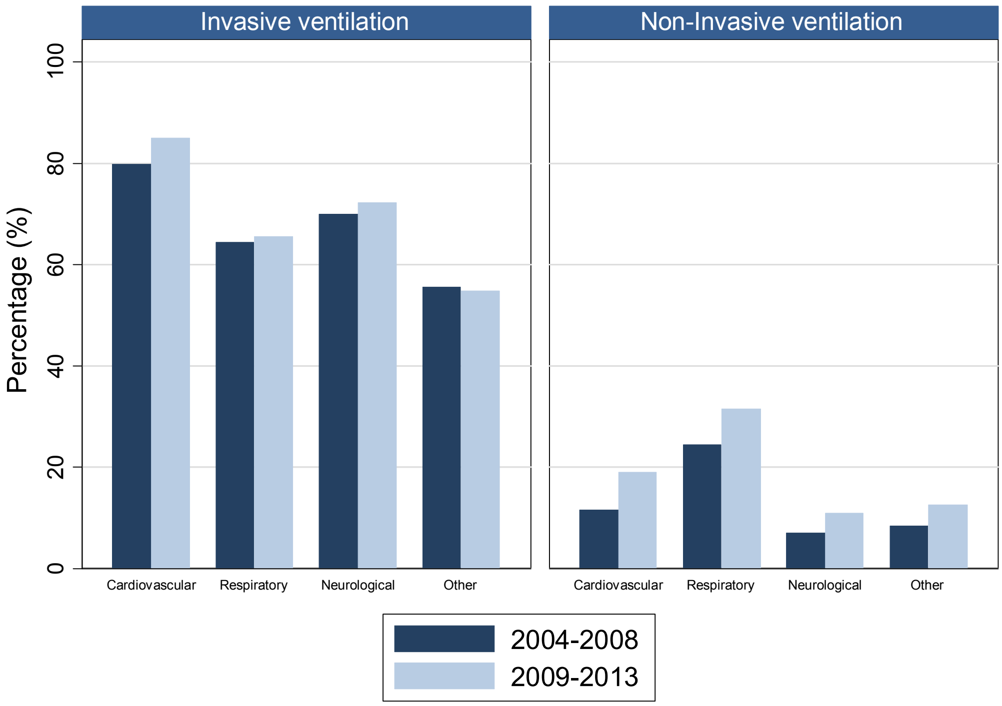
Figure 4. Percentage of admissions to PICUs where ventilation was administered for children residing in England and Wales only by age, split by 5-year periods (2004-2013)



Ventilation by diagnostic group

Across diagnostic groups; the percentage of patients invasively ventilated was highest amongst the cardiovascular (82.6%) and trauma (74.5%) diagnostic groups and lowest amongst admissions with oncology as the primary diagnostic group (36.8%). Non-invasive ventilation showed a slightly different pattern with the highest percentage amongst those who had multisystem (28.2%) or respiratory (20.0%) related primary diagnoses and lowest amongst those with trauma (3.8%). To explore differences over time admissions were split by the three most common primary diagnoses and all other admissions were grouped (Figure 5). Levels of IV increased between the two periods in the cardiovascular group from 79.9% in 2004 to 2008 to 85.0% in 2009 to 2013. An increased use of NIV occurred across all diagnostic groups between the two periods.

Figure 5. Percentage of admissions to PICUs where ventilation was administered for children residing in England and Wales only by diagnostic group, split by 5-year periods (2004-2013)



Ventilation by unit

During the ten year period variations in the percentage of children receiving each type of ventilation were seen by unit (Figure 6a and b) and illustrates within the national data how individual units have variation in levels of ventilation given to patients due to factors such as patient case-mix and clinical practice differences. Only children residing in England and Wales were included to make the data comparable with that used in the rest of the article, units with no patients in either time period or less than 100 patients overall were excluded.

Figure 6a. Percentage of admissions to PICUs where invasive ventilation was administered for children residing in England and Wales only by unit, split by 5-year periods (2004-2013)

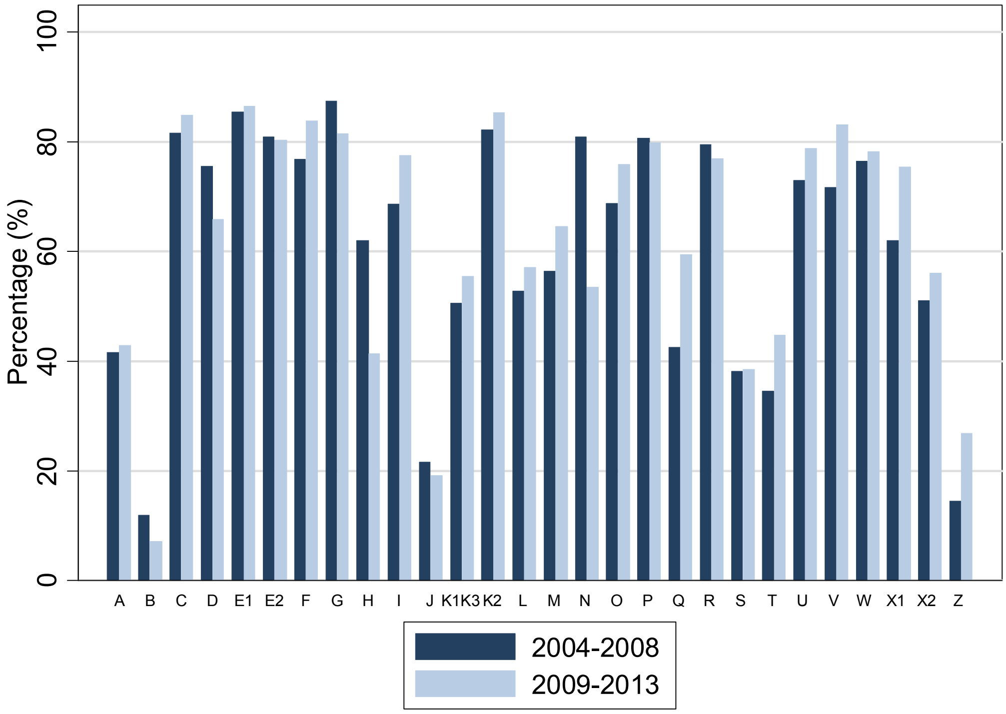
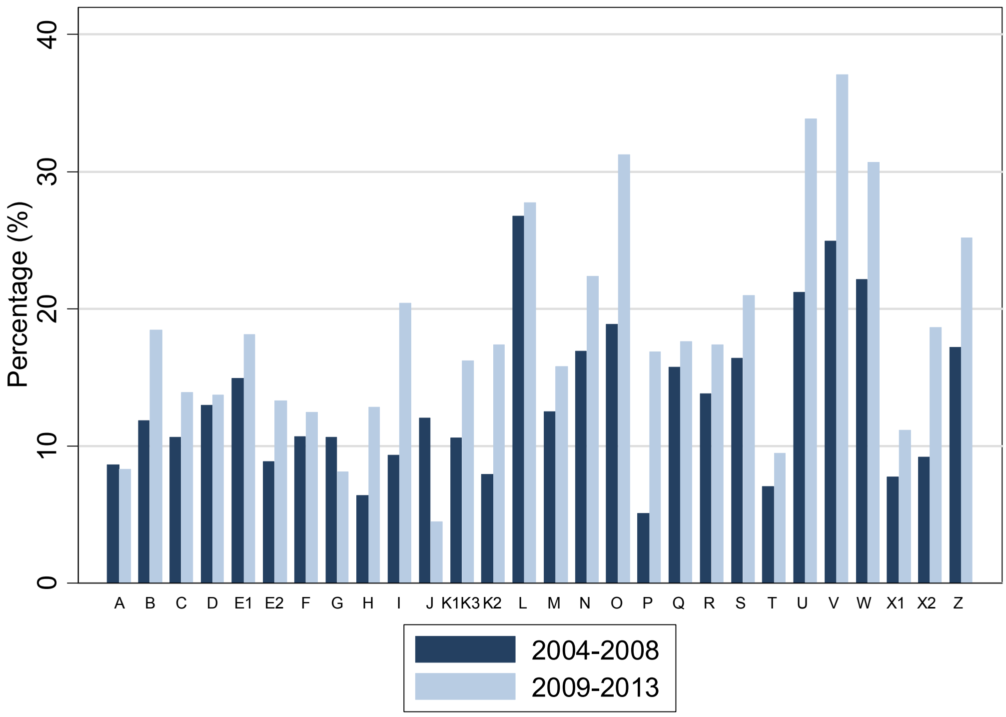


Figure 6b. Percentage of admissions to PICUs where non-invasive ventilation was administered for children residing in England and Wales only by unit, split by 5-year periods (2004-2013)



Limitations and Uncertainties

Data on ventilation is only provided once per day, therefore if a child was on each for part of one day that would count as a day of invasive and a day of non-invasive in these calculations and therefore length of ventilation will include a small over-estimation.

Discussion

This analysis of ventilation using 10 years of PICANet data throws up some interesting findings but leaves a number of questions unanswered and worthy of further study. The key findings are an increased use of non-invasive ventilation, and an increase in the proportion of cases who receive both NIV and IV. At the same time there has been a reduction in the proportion of cases who receive no form of ventilation and little change in the proportion of cases who receive invasive ventilation. Large inter-unit differences in the use of different ventilation strategies are evident.

There are many possible explanatory variables behind the apparent increased use of NIV but there are limits to how far these can be explored. Use of whole admission data is relatively crude and doesn't allow us to explore use of ventilation in greater detail, for example the order of IV and NIV in cases who receive both therapies, or the use of NIV post extubation. A more granular analysis using daily PCCMDS data is planned to explore this further.

A number of factors unrelated to changes in clinical approach may explain some of the findings. Changes in PICU admission threshold will have an impact on the percentage of cases requiring ventilation or any other ICU intervention. Ideally an analysis of this type should include some correction for disease severity at PIC admission.

As highlighted in the introduction it is possible that the NIV group is 'contaminated' with some cases receiving high flow nasal cannula therapy, and this could in part explain the increase in NIV in the 2009-2013 era. Separate identification of high flow therapy will greatly assist in the future and allow us to investigate what effect it is having. Of particular interest will be the 'failure' rate for high flow therapy and whether its use is associated with a prolongation of 'respiratory weaning' and a prolongation of PICU stay.

It is interesting to speculate why the percentage of children receiving neither type of ventilation is falling, is it that the illness severity of patients admitted to PICUs has increased or has our threshold for intervention lowered such that patients who would previously have received neither now receiving ventilation? How much of this is nasal high flow therapy and how much is it NIV?

Accepting the above limitations and unanswered questions ventilation practices appear to have changed over a decade with greater use of NIV.

The median duration of both non-invasive and invasive ventilation has stayed relatively stable over the last decade but as the number of PICU admissions has increased the absolute number of children receiving ventilation at any one time has increased, requiring an increase in PIC resources.

The proportion of children receiving prolonged ventilation (>21 days) has shown a small but steady increase over the past 7 years. Again this translates into a greater increase in the numbers of cases in PICUs. It would be interesting to know how many of these children are tracheostomy ventilated and what outcomes are achieved after prolonged ventilation.

Despite ventilation being a central component of critical care practice there have been too few trials of ventilatory support undertaken in PICU and there are too many questions that we don't have answers to. PICANet data provides a rich source for understanding current practice and outcomes, and we should be using the data to generate research proposals.

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Changing patterns of interventions used in paediatric intensive care over the last decade

Clinical review by Dr Claire Westrope
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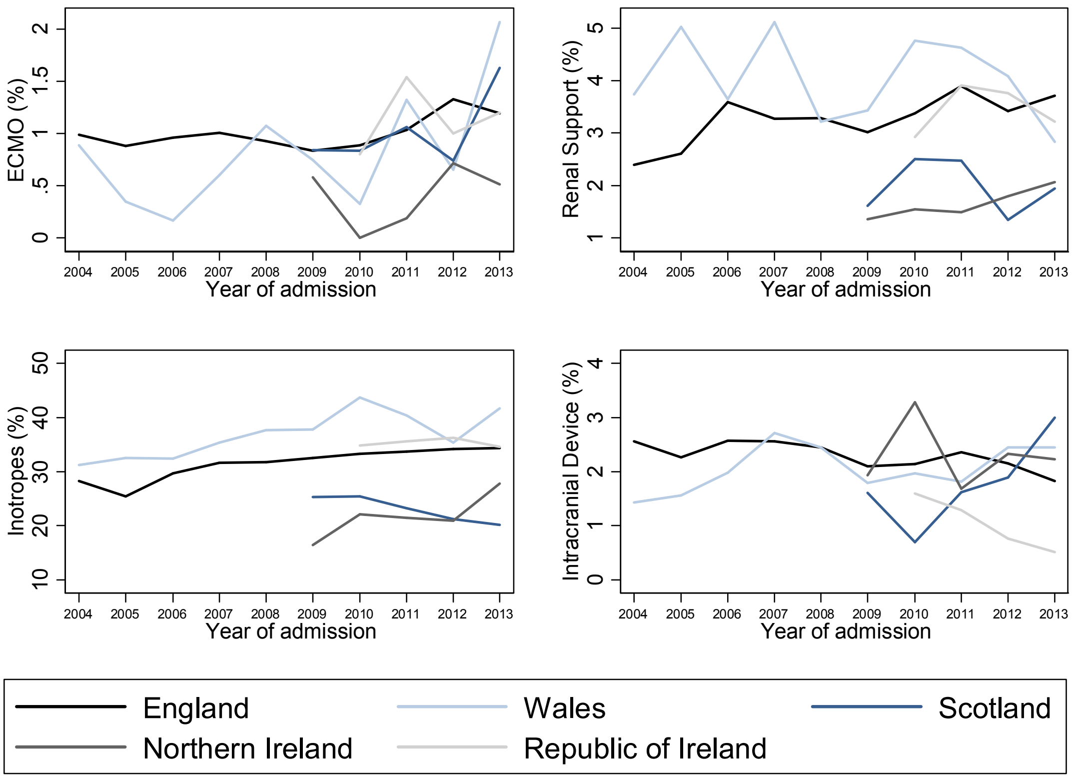
PICANet has collected summary information on a limited number of important interventions carried out in PICU since data collection commenced in 2002. In this article we compare the proportion of children receiving four interventions (Extracorporeal membrane oxygenation (ECMO), renal support, inotropes and the placement of an intracranial pressure device) over the last decade in the UK by the child's country of residence. Figure 1 provides a summary of all four interventions by year for each country between 2004 and 2013.

Figure 1. Percentage of admissions to PICUs in the UK receiving ECMO, renal support, inotropes or an intracranial pressure device by year of admission between 2004 and 2013 by country of residence



ECMO

Extracorporeal membrane oxygenation (ECMO) also known as Extracorporeal life support (ECLS) has been developed for use in patients with respiratory or cardiac failure [1]. ECMO was previously reported on in the 2011 PICANet annual report in an article discussing mortality across the different diagnostic groups and cardiac centres [2].

In 2013, the most recent year reported, the percentage of children admitted to PICU who received ECMO varied between 2.1% for Welsh residents to 0.5% for those from Northern Ireland. In England and Wales there was a small increase per year in ECMO over the decade from 0.99% of children admitted to PICU in 2004 to 1.23% in 2013 (Figure 1) (average increase of 0.03% per annum, p=0.05). This increase appeared to be mainly in children in the youngest age group (<1 year old), who also had the highest percentage of children receiving ECMO (Figure 2a).

The Extracorporeal Life Support Organization (ELSO) Registry which has collected outcome data on over 56,000 patients including neonatal and paediatric admissions have found increases in respiratory ECMO use during the H1N1 epidemic in 2009 and increasing use in cardiac settings [3]. This was explored in the PICANet data-set by splitting admissions into primary diagnoses groups of cardiovascular, respiratory and other (Figure 2b). There was evidence of increasing use in cardiovascular patients but the 2009 H1N1 pandemic did not appear as a spike.

Figure 2a. Percentage of children resident in England and Wales receiving ECMO by age group and year, 2004 to 2013

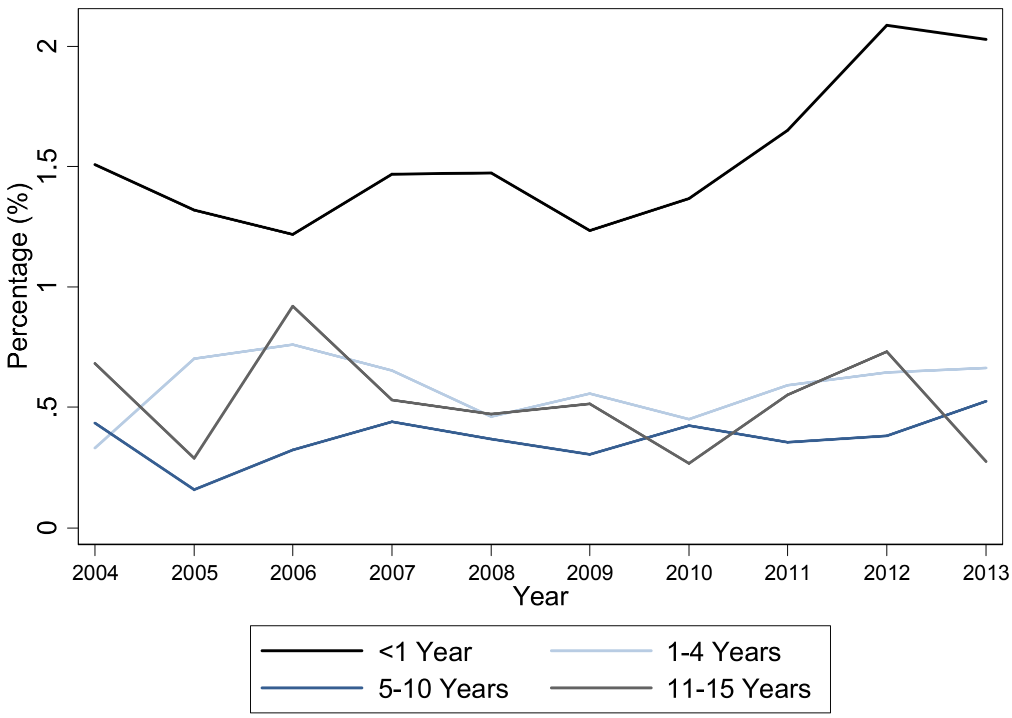
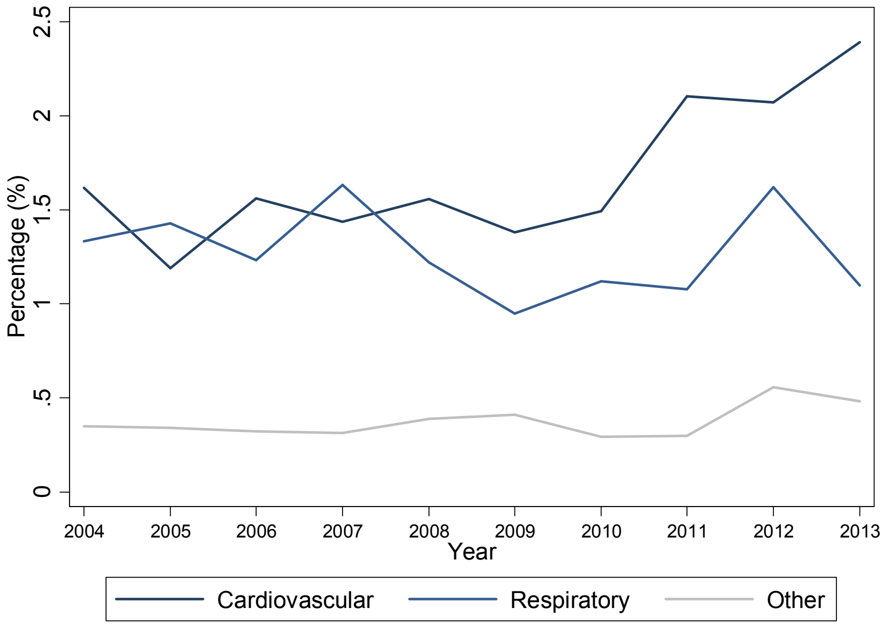


Figure 2b. Percentage of children resident in England and Wales receiving ECMO by diagnostic group and year, 2004 to 2013



Renal support

Renal replacement therapy (RRT) and support is used in paediatric intensive care to manage patients with acute kidney injury and its consequences; mainly fluid overload and electrolyte and acid base imbalance. RRT can be delivered using the peritoneum as a dialysis membrane (pd) or using extracorporeal modalities (where blood is filtered outside the body). Extracorporeal therapies are used intermittently (intermittent haemodialysis) or continuously (continuous renal replacement therapy (CRRT). In our dataset 'Haemofiltration' is used synonymously with 'CRRT', so may encompass CRRT modalities utilising convective and diffusive (or both) strategies of RRT [3].

In 2013 the percentage of admissions where RRT was required varied from 2.1% in those resident in Northern Ireland to 3.7% in England (Figure 1). Using the England and Wales data only there was evidence of an increase in renal support over the ten year period (average increase of 0.1% per year, p=0.02). The level of administration was similar across all age groups (Figure 3a). All types of RRT showed a similar small increase in the percentage of admissions receiving this as an intervention (Figure 3b).

Figure 3a. Percentage of children resident in England and Wales receiving renal support by age group and year, 2004 to 2013

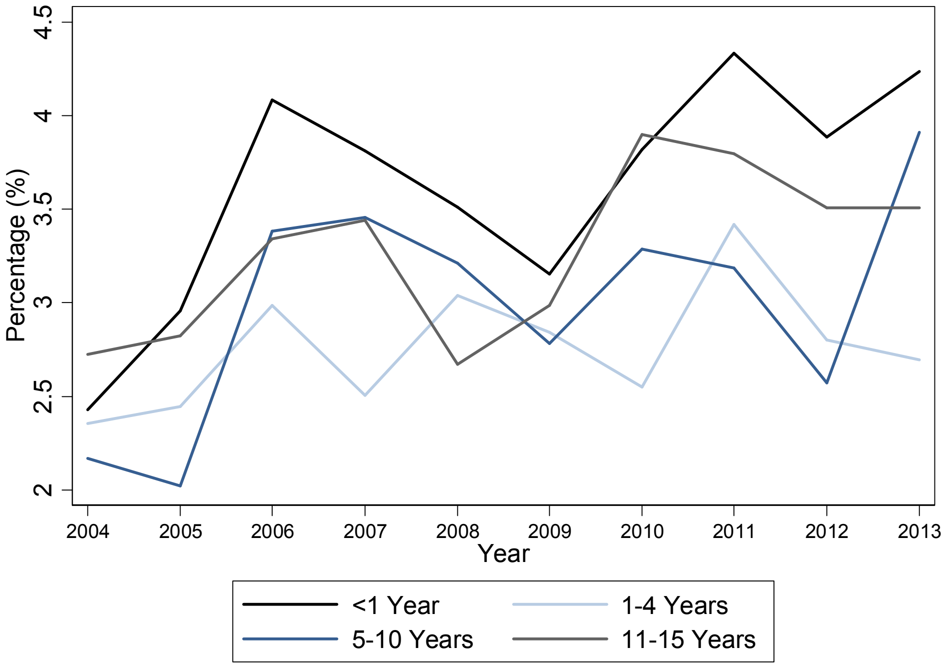
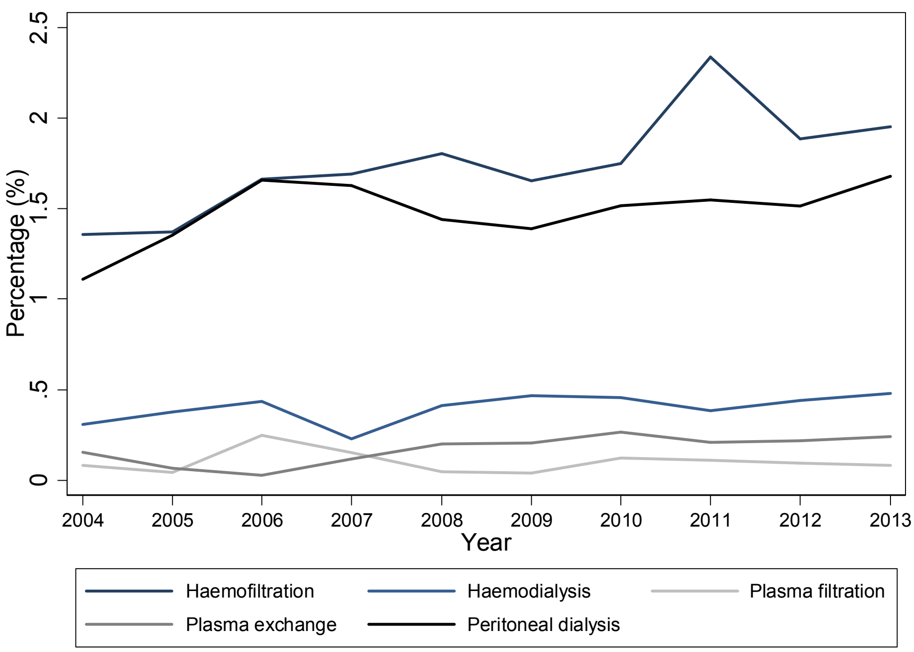


Figure 3b. Percentage of children resident in England and Wales receiving renal support by type of renal replacement therapy and year, 2004 to 2013*



* A child could receive more than one type of renal support on a given admission.

Inotropes

Inotropic medication is used to increase the force of contractions of the cardiac muscle [5]. A large percentage of children receive inotropes during their PICU admission. Inotrope usage in 2013 varied from 20.2% in children resident in Scotland to 41.6% for those resident in Wales. For English and Welsh children an increase in the use of inotropes was seen over the 10 year period (average increase of 0.86% per year, p< 0.001) and this increase was most marked in those under 1 year of age (Figure 4a). As expected, patients with a primary cardiovascular diagnosis were most likely to be given inotropes and this patient group had the most increase in use from 53.3% to 75.1% (Figure 4b).

Figure 4a. Percentage of children resident in England and Wales receiving inotropes by age group and year, 2004 to 2013

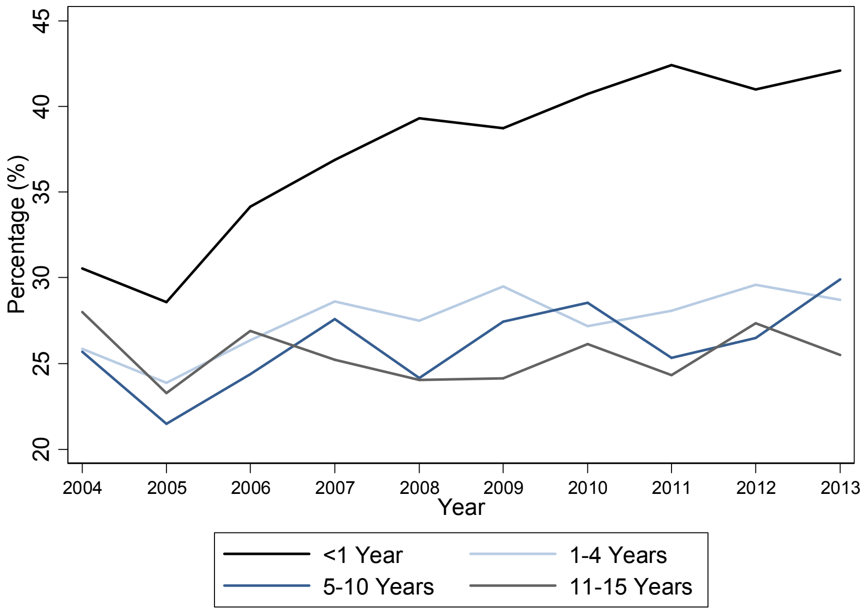
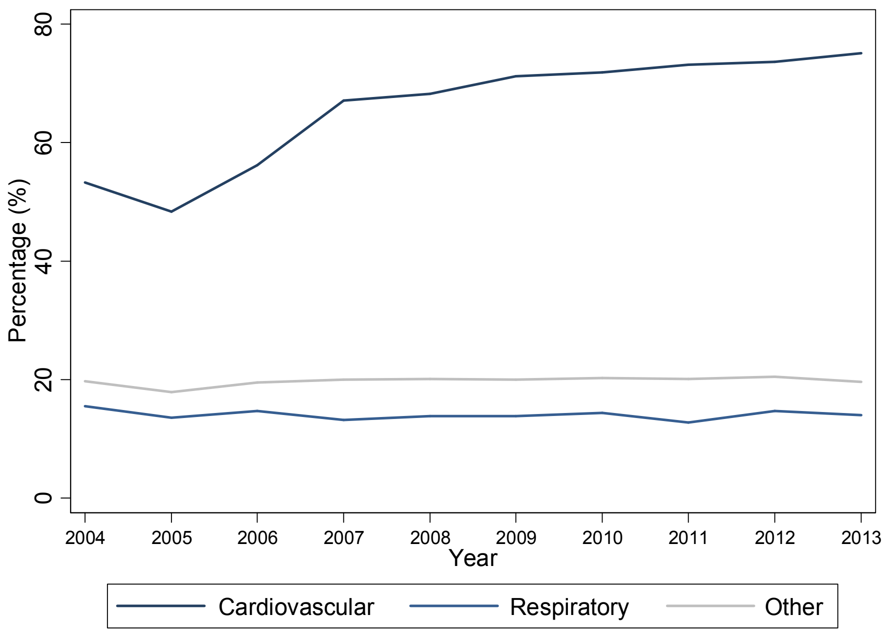


Figure 4b. Percentage of children resident in England and Wales receiving inotropes by diagnostic group and year, 2004 to 2013



ICP monitoring

Intracranial pressure monitoring is used where raised intracranial pressure is suspected due to mechanisms such as swelling and haemorrhage [5, 6]. In 2013 the percentage of admissions where intracranial pressure monitoring was used varied from 0.5% in children resident in the Republic of Ireland to 3.0% for those living in Scotland. For English and Welsh children there was no evidence in changes in the percentage of children receiving ICP monitoring during the last ten years (average decrease of 0.06% per year, p=0.02). It was the only selected intervention where rates were higher in the oldest group of children and lowest in the youngest mainly due to the mechanism of injury for which ICP monitoring is mainly used: traumatic brain injury (Figure 5a) [5]. Although overall rates have not changed greatly there was a significant (p<0.001) reduction for children aged 11-15 years from 7.3% to 4.3%. Figure 5b shows that the diagnostic group most likely to receive ICP monitoring is those admitted due to trauma, a significant proportion of children in the neurological and oncology diagnostic groups also received ICP monitoring (Figure 5b).

Figure 5a. Percentage of children resident in England and Wales receiving intracranial pressure monitoring by age group and year, 2004 to 2013

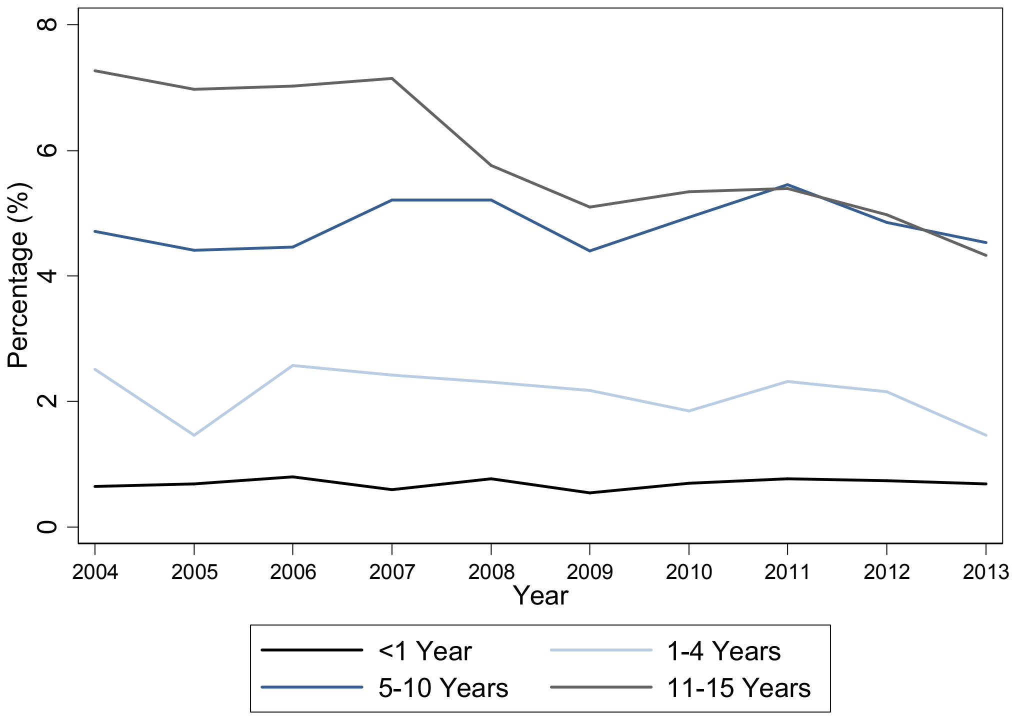
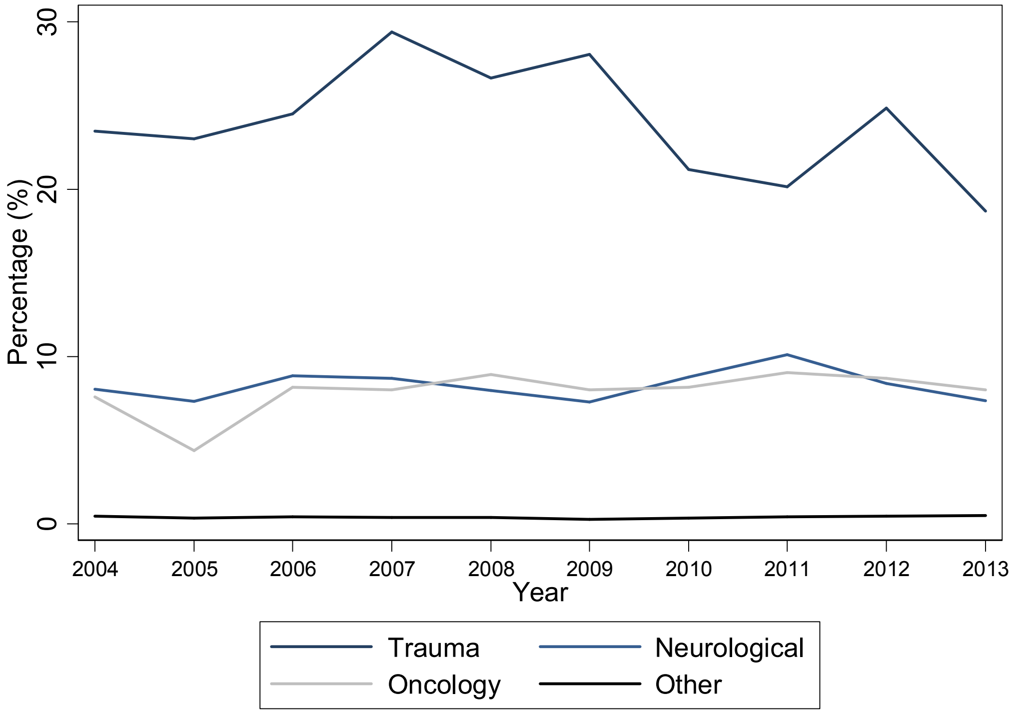


Figure 5b. Percentage of children resident in England and Wales receiving intracranial pressure monitoring by diagnostic group and year, 2004 to 2013



Limitations and Uncertainties

Coding and definitions have changed over time, for example, within the definition of renal replacement therapy, different units can have different coding practices and this may lead to differences in reporting. In the early years of PICANet missing data occurred in some cases if full observations could not be collected or entered on all patients. Both these factors may lead to artefactual changes in the percentage of children receiving an intervention over time.

Discussion

PICANet continues to add to the evidence base available for exploring the case-mix of children receiving interventions in PICUs such as those illustrated here. The data collected through PICANet can be used to describe the epidemiology and clinical characteristics of children who receive such interventions. Outcomes for children receiving different interventions during their stay; including in-unit mortality, length of stay and rates of re-admission to PICU can be monitored. Now PICANet has been established for several years; further examination of long term patient outcome several years after a PICU admission can also be carried out including mortality through linkage to Office of National Statistics data.

Over time, especially in the last decade, modern approaches are guided by new technology which has included advances in available drugs, clinical equipment used such as ECMO and RRT and the ability to continuously monitor routine observations. This facilitates the rapid assessment of patient response to treatment and any change in their condition allowing treatment pathways to be chosen accordingly.

Future analysis within PICANet will include more work to understand why changes in interventions have taken place. Continuing changes may affect what interventions are required in future years which would impact on resource use. Information on other high cost interventions e.g. surfactant and also the order interventions are administered can give information about changes in practice. Certain interventions are a major predictor of how ill the child was when entering intensive care and following up whether a child goes on to have a good or poor outcome can help inform the parents of children who receive specific interventions.

Clinician's commentary

These interventions are illustrative of the types of interventions that are used in PICUs, for which the evidence base for what clinical indication and treatment approach should be used to gain optimal patient outcomes is difficult to assess, as in many cases randomised controlled trials (RCTs) are not available [8]. All of these interventions lack robust evidence from RCTs yet have become more acceptable and common place over time in PICUs who contribute data to PICANet. Using PICANet data we can contribute to the evidence base with large numbers of patients treated in comparison with most reports in the literature.

Any explanation of changes in levels of intervention will need to take into account the effect of changes in innovation/technology. For example, a recent comparison of ECMO outcomes and circuit complications pre and post change in circuit technologies (roller pump and silicon oxygenator vs. centrifugal pump and PMP oxygenator) showed better survival and less complications with the newer systems [8]. As these technologies get simpler and safer they are likely to get used more widely.

Giving possible reasons for the findings for each intervention:

ECMO – There was no spike in the use of ECMO in PICUs in the year of the major H1N1 outbreak. Although H1N1 led to an increase in respiratory ECMO use this was predominantly in adult patients and there was little change in paediatric/neonatal respiratory ECMO activity.

In line with provision of ECMO becoming standard for centres performing paediatric cardiac surgery, use of ECMO in the cardiac surgical population (which is predominantly in neonates and infants) has increased. This is also true worldwide as seen in the ELSO Registry data [2].

Renal support - The true incidence of Acute Kidney Injury (AKI) in the paediatric ICU population is unknown, partly due to the fact that until publication of Kidney Disease – Improving Global Outcomes (KDIGO) guidelines in 2012 no consensus definition for AKI existed [9]. Therefore historical reports of incidence vary depending on the population studied and the definition used [10].

Published data for the adult population show that between 5-25% of patients in ITU develop AKI and around 6% of these patients require RRT [10]. Paediatric data suggests that the incidence of AKI may be as high as 40% in children post cardiac surgery [11]. RRT requirement in patients on PICU is associated with higher than expected mortality [12]. In patients requiring ECMO, RRT use is an independent risk factor for mortality [13].

Technological advances, familiarity with techniques and anecdotal data regarding positive outcomes could all be factors in the small overall rise in renal support. It is possible the increase in RRT use in children less than one year of age goes alongside the increase in cardiac surgery in neonates and infants, similar to cardiac ECMO.

The formal definition of AKI in 2012 facilitates diagnosis and should result in a natural increase in awareness and diagnosis of AKI in the paediatric population, which is likely to lead to an increased use of renal support in the future. Robust evidence through the conduct of RCTs will also give more evidence on when to initiate RRT, which modalities are best to use and which are most efficient at fluid removal.

ICP monitoring – Organisational changes including the introduction of major trauma centres are likely to influence the pattern of the use of ICP monitoring across England as changes occur in where paediatric trauma patients are treated [14]. Changes in the number of trauma cases, for example due to road safety or similar public health campaigns may also affect the need for ICP monitoring. A recent study of traumatic brain injury in Scotland found an average annual percentage reduction of approximately 5% per year for both boys and girls aged 0-14 in hospital admission rates over the last ten years, the authors suggested 'effective prevention measures including; legislation for child restraints in cars, improvements in the safety and design of children's equipment as well as a reduction in the number of child pedestrians and cyclists' had contributed [15]. This is reflected in the reduction in ICP monitoring over time for children in the 11-15 year age group.

When trying to understand the changes in interventions over time the boundaries between established therapy, innovative therapy and research can be quite fluid. Advances in innovation/knowledge and technology in all aspects of medicine results in an eternally evolving clinical environment where previously accepted interventions are questioned and new interventions developed, which in turn results in unique and novel clinical situations to which clinicians have to adapt and respond. For example, in hematopoietic stem-cell transplantation (HSCT) overall outcomes have improved over time with evolving techniques [16]. HSCT is also being used in novel ways, such as to halt neurological degeneration in patients with Mucopolysaccharidoses [17]. Historically mortality in patients who have undergone HSCT who then require ECMO is reported to be very poor to the extent that in some centres HSCT (for whatever underlying diagnosis) is an absolute contraindication to ECMO [17]. In the current climate, with new unique patient populations and advances in technology such boundaries should be continuously reassessed. Information such as this 10 year summary of data from PICANet, separate from that available from RCT's, significantly contributes to our knowledge and understanding of the application of these interventions.

To paraphrase Wolfson et al. [20]:

'The boundaries among standard therapy, innovative therapy, and research can be quite fluid. This data illustrates the imperative to consider therapies that may be appropriate for a critically ill child even without evidence predictive of success, to have entry criteria and treatment protocols for such therapies, and to collect data from such experiences to advance the standard of care.'

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DISTANCE BETWEEN HOME ADDRESS AND TREATING UNIT OVER TEN YEARS OF INTENSIVE CARE TREATMENT

Clinical review by Dr Padmanabhan Ramnarayan
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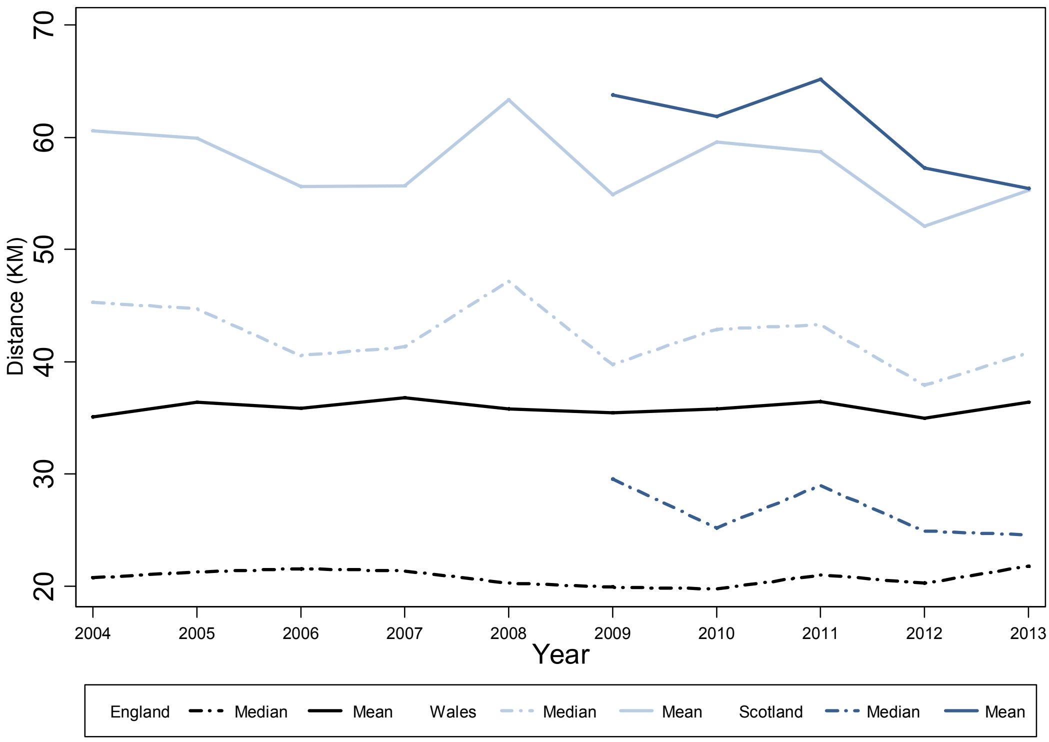
Background

Paediatric intensive care services have been centralised in the United Kingdom since the late 1990s. While centralisation of specialist services such as PICU confers significant benefits in terms of concentrating skills and expertise in a smaller number of high-volume centres, it also inevitably increases the distance sick children have to travel for specialist care. Timely access to expert care has been shown to improve patient outcome, particularly in conditions such as traumatic brain injury and septic shock; therefore, it is vital that the effects of centralisation on access to PICU is monitored, especially for emergency admissions.

PICANet collects details of patient's home addresses on admission and these have been used to calculate the Euclidean distance between their home and the admitting PICU using grid reference data linked to postcode from the National Statistics Postcode Directory [1]. We have previously used PICANet data to explore the relationship between mortality and distance to admitting PICU when investigating the performance of the specialist transport service [2, 3]. Here we analyse trends in the distance from home address to admitting PICU over the last ten years.

Figure 1. Mean and median distances from home address to treating PICU, 2004-2013*



* Distances for Northern Ireland and Republic of Ireland were not available

Distances were calculated using straight-line distance from provided home address to treating hospital using postcode data, 103 distances of 0km were excluded. Figure 1 shows the distances for children resident in England, Scotland and Wales. As the data were skewed (with some exceptionally long journeys) mean distance travelled was greater than median distance, especially for Scotland. Median distances in 2013 were 21.8km for England, for 40.8km Wales and 24.6km for Scotland.

Findings

Comparing data over the years (Figure 2 and Table 1) there has not been a change in the median distance travelled in England or Wales with distances remaining similar over time.

Figure 2. Histogram distances from home address to treating PICU for England and Wales in 5 year periods, 2004-2013

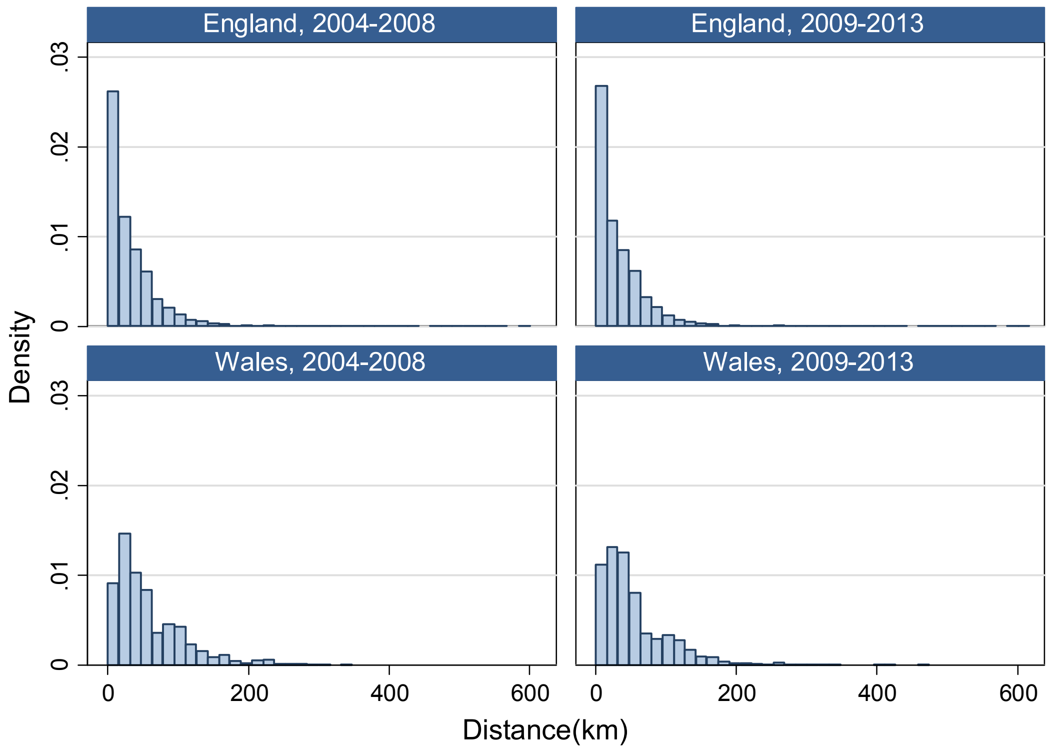


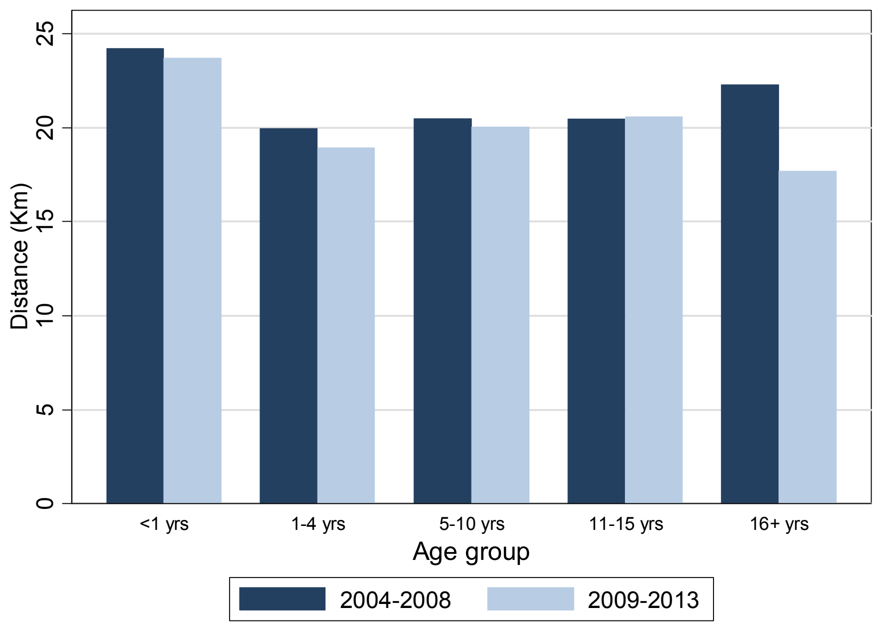
Table 1. Summary of distances to admitting PICU (in km) for England and Wales, 2004-2013

	Number of Admissions	Mean	Min	Q1	Median	Q3	Max
England							
2004	13,121	35.1	0.1	8.5	20.8	47.0	563.5
2005	12,926	36.5	0.1	8.9	21.4	48.7	556.4
2006	13,214	35.9	0.1	9.1	21.6	47.9	588.1
2007	13,754	36.8	0.1	8.4	21.4	48.8	558.4
2008	13,930	35.8	0.2	8.1	20.3	48.2	568.4
2009	14,496	35.5	0.1	7.8	20.0	47.3	607.3
2010	14,875	35.8	0.2	7.8	19.8	47.9	606.5
2011	14,701	36.4	0.1	8.3	21.0	49.0	566.8
2012	15,501	35.0	0.1	8.2	20.3	47.8	553.4
2013	15,290	36.4	0.2	8.9	21.8	48.5	558.3

Wales							
2004	563	60.6	0.6	23.8	45.3	86.7	270.2
2005	577	59.9	1.2	24.7	44.7	85.2	339.5
2006	604	55.6	1.2	21.5	40.5	78.6	312.2
2007	664	55.7	0.6	23.0	41.3	80.8	344.9
2008	653	63.4	0.5	23.7	47.2	91.7	295.4
2009	671	54.9	0.9	22.1	39.8	67.8	470.7
2010	610	59.6	0.8	25.1	42.9	74.0	416.4
2011	605	58.7	0.5	25.6	43.3	84.3	416.4
2012	613	52.1	0.5	15.6	37.9	72.3	273.3
2013	531	55.3	0.9	21.3	40.8	65.6	328.7

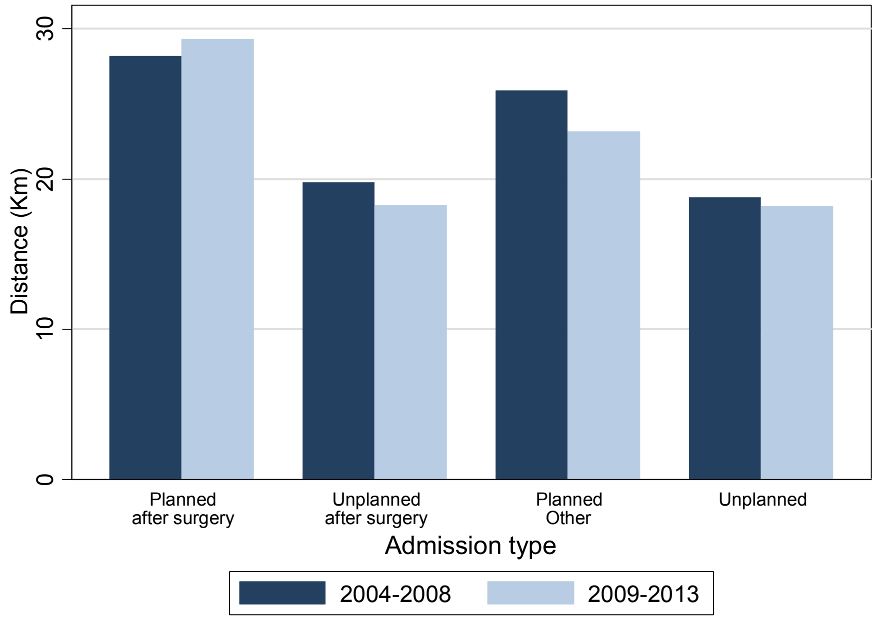
There was little change in distance travelled between the first five and last five years of admissions in terms of median distance (Figure 3).

Figure 3. Median distances from home address to treating PICU for children residing in England and Wales only by age, split by 5-year periods (2004-2013)



Planned admissions had the highest median distance: 28.7km for PICU admission after surgery and 24.3km otherwise. For unplanned admissions, this was 18.9km (PICU admission after surgery) and 18.4km otherwise (Figure 4). There has been little change for any admission type between the first five and last five year period.

Figure 4. Median distances from home address to treating PICU for children residing in England and Wales only by admission type, split by 5-year periods (2004-2013)



Concentrating on unplanned admissions only to examine the effect of retrievals (as it might be expected that admissions that were via retrieval were to a PICU further from the child's home address), it was confirmed that children who were retrieved travelled a median distance of 30.5km, compared to 9.6km for those children who were not (Figure 5). There was little evidence that these distances have changed over time.

Figure 5a. Median distances from home address to treating PICU for unplanned admissions for children residing in England and Wales only by retrieval status, split by 5-year periods (2004-2013)

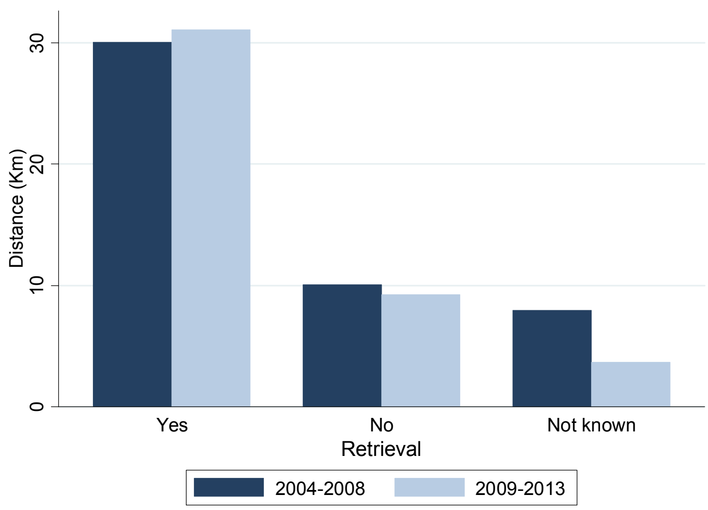
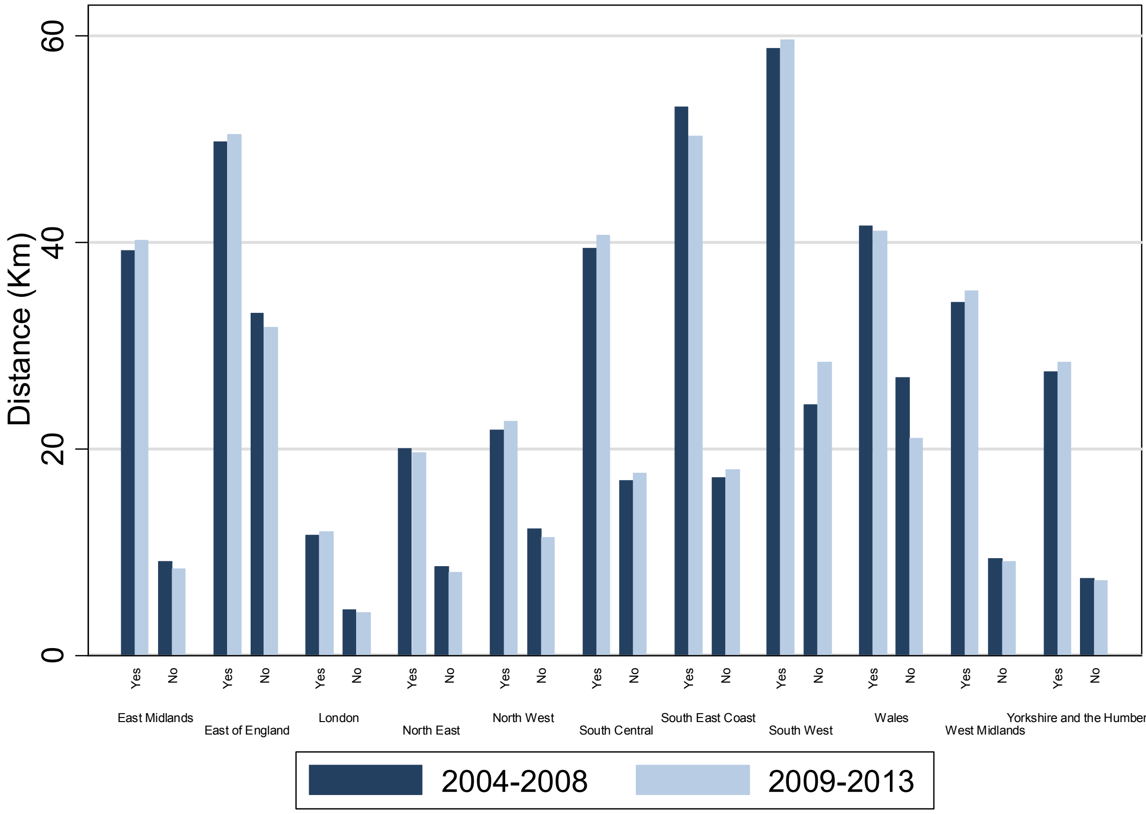


Figure 5b. Median distances from home address to treating PICU for unplanned admissions for children residing in England and Wales only by retrieval status and SHA, split by 5-year periods (2004-2013)



Limitations and Uncertainties

These analyses use the distance from home to PICU; however, distance travelled from home to the first treating hospital, and then from the first treating hospital to PICU, might be more informative, in terms of providing a complete picture of the entire patient pathway. In addition, road distance, rather than Euclidian distance, might provide a better estimate of the total distance travelled.

Distance in this context is used as a proxy for time. This assumption may not hold true, and shorter distances from home to PICU may still be associated with lengthy delays in reaching a PICU, and vice versa.

Discussion

Despite the limitations highlighted above, these data provide, for the first time, a detailed picture of the distance travelled by children, both for planned and unplanned PICU admissions. That these distances are not large, and have not changed much over the past decade, is reassuring. This may reflect the fact that there have been no major re-organisations of PICU services in the past decade. However, these findings will be useful as a benchmark for future assessments, particularly at a time when further changes to centralisation of specialist services are being considered.

The new PICANet transport dataset also offers the valuable opportunity to perform detailed analyses in the future, focusing on how distances children are transported and other factors relating to transport might impact on patient outcome. As specialist services such as PIC and PIC transport evolve in the future, PICANet data will continue to remain an important resource for clinicians and commissioners.

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TRENDS IN PAEDIATRIC INTENSIVE CARE NURSE STAFFING OVER THE LAST TEN YEARS

Clinical review by Ghislaine Stephenson, PICU Lead Nurse, Great Ormond Street Hospital & Dr Paula Lister, Paediatric Intensivist, Great Ormond Street Hospital

Nurses comprise the largest part of the workforce within paediatric intensive care where a high ratio of nurses to patients is required to provide specialist skilled nursing care [1]. Over the last decade there has been a steady increase in the number of nurses employed in this specialist service setting which has been matched by an increase in the number of beds and admissions. Since 2003 PICANet has collected data on staffing levels within PICUs and has a remit to audit the appropriate Standards of the Paediatric Intensive Care Society (PICS) [2].

The first "snap shot" survey looking at the status of the nursing workforce within PICUs was introduced in 2003, and data were collected from 88% (22) of the 25 participating organisations in England and Wales. Over time the number of units submitting data to PICANet has increased and now includes 35 units in the United Kingdom and Ireland.

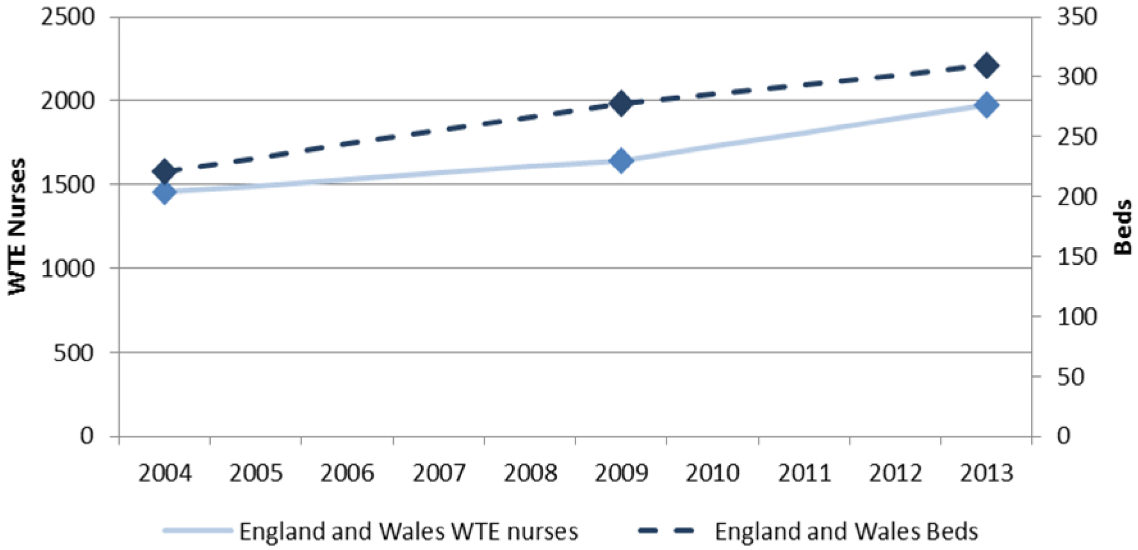
Staffing data were collected in 2003, 2004, 2005, 2009, 2010, 2011, 2012 and 2013. During 2006-2008 PICANet participated in the study analysing the 'Impact of changing workforce patterns in UK paediatric intensive care services on staff practice and patient outcomes' [3]. Over time the staffing questionnaires, designed in order to assess levels and grades of PICU staff, have been refined. Information is collected on numbers of nursing staff and medical staff employed on units, during a specified week in the final quarter of each year.

Under the Agenda for Change established in 2004 [4], NHS pay scales are by bands rather than grades. Four units continue to apply grades in 2013, for the purpose of this report grades A-C are mapped to bands 2-4, grades D-E to band 5, grade F to band 6, grade G to band 7 and grades H-I to band 8.

The above changes and the limitations of data collection, prior to 2009; means that longitudinal data for inclusion in this analysis is only available for NHS organisations in England and Wales. For this analysis three time points have been selected to show the changes in staffing over the ten year period, 2004, 2009 and 2013.

Figure 1 shows the number of whole time equivalent (WTE) clinically qualified nurses compared with the number of funded critical care beds in England and Wales, 2004–2013.PICANet received nurse staffing data from all units (n=24) submitting admission event data to PICANet in England and Wales in 2004; organisation J (1 ITU bed) ceased to submit data in August 2010 and organisation Z (2 ITU & 4 HD beds) joined PICANet in 2007 submitting staffing data in 2009 and 2013.The number of beds reported is the number of PIC and high dependency beds for which PICANet receives admission event data. Nurse to funded beds ratios are calculated using a 1:1 ratio (beds/nurse) for intensive care and 0.5:1 for high dependency.

Figure 1. Number of whole time equivalent (WTE) nurses and beds in NHS PICUs in England and Wales



Over the period 2004 to 2013 there has been a 35.7% (520 nurses) increase in the number of WTE clinically qualified nursing staff employed to provide patient care and a 40.1% (n=88) increase in the number of beds. This equates to a small reduction in the ratio of WTE clinically qualified nurses to the number of beds in England and Wales over the period reported.

Table 1. The ratio of WTE clinically qualified nurses to beds in 2004, 2009 and 2013

	2004	2009	2013
Nurses	1,456.70	1,643.20	1,976.70
Beds	221.00	278.00	309.50
WTE Nurses:Beds	6.59	5.91	6.39

*Note: The number of beds is calculated as paediatric intensive care =1 and high dependency =0.5

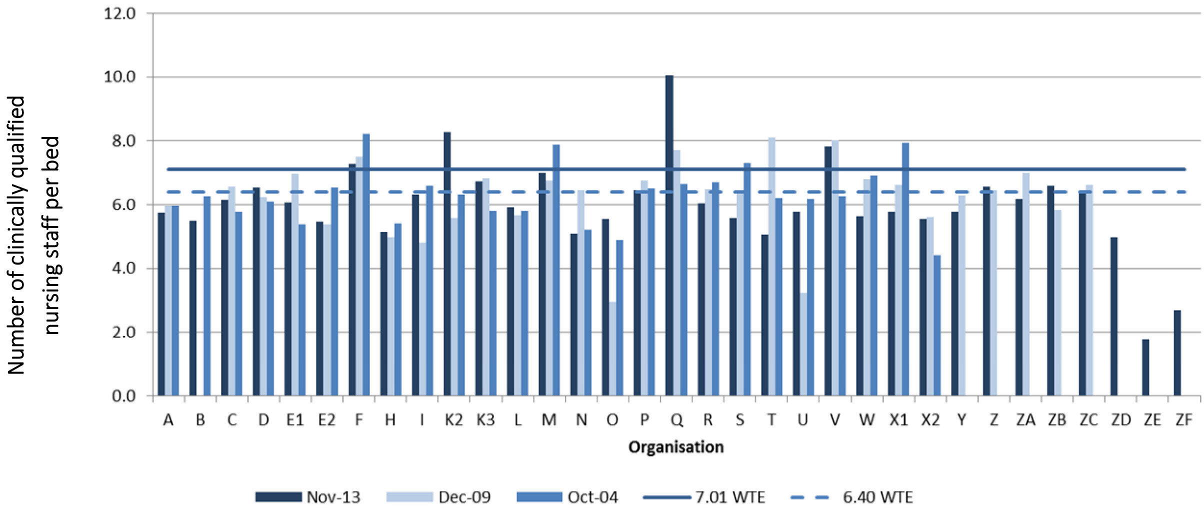
Table 2. The number and proportion by band of the WTE qualified nurses employed in PICU to deliver clinical care in England and Wales by band in 2004, 2009 and 2013

	5	(%)	6	(%)	7	(%)	8-9	(%)	Total band 5-9
2004	1,001.8	(68.4)	291.6	(19.9)	163.3	(11.2)	7.5	(0.5)	1456.7
2009	1,024.0	(61.7)	418.1	(25.1)	201.1	(12.1)	17.3	(1.0)	1643.2
2013	1,288.7	(64.4)	490.3	(24.5)	197.6	(9.9)	25.2	(1.3)	1976.6

Table 2 shows an increase in the total number of WTE qualified nurses which reflects the increase in the number of beds over the decade. There is also an increase in the number and proportion of band 6 nurses in 2009 and 2013 compared with 2004 although this could partially reflect the change in nursing bands following ‘Agenda for Change’.

Figure 2 shows the total number of WTE clinically qualified nursing staff per funded bed, in post to provide clinical care in 2004, 2009 and 2013. Data for all qualified nursing staff and the number of funded beds are calculated from the data returned by 25 units in England and Wales in October 2004 and is compared with data received in December 2009 (29 units) and in November 2013 (33 units).

Figure 2. Number of clinically qualified staff in post (WTE) per bed, by health organisation: 2004, 2009 & 2013



Nurse staffing data are collected annually to monitor PICS Standard 164 of the revised PICS Standards for the Care of Critically Ill Children (4th edition) Version 2, June 2010 and to identify any major nursing issues.

PICS Standard 164. The units nursing establishment and nursing rosters should be appropriate to the anticipated number and dependency of patients.

Staffing levels should be based on the ratio in Appendix 13 which states:-the minimum number of qualified nurses required to staff one critical care bed is, at least 7.01 whole time equivalents (WTE).

Previous standards endorsed the benchmark of 6.4 WTE per bed. The Royal College of Nursing (RCN) recommends a minimum of 25% uplift to nursing establishments to cover annual leave, study leave and sick leave. Additional considerations are mandatory and statutory training, maternity, special leave and an allowance for a nurse in charge and/or runners. The final calculation takes the minimum WTE per bed to 7.01. This guideline and the previous guideline of 6.4 WTE per bed are shown in Figure 2.

In 2004, 24% (6/25) of organisations in England and Wales met the previous guideline of 6.4 WTE qualified nurses per bed (Figure 2). During the next five years the numbers of organisations submitting data to PICANet increased and in 2009 45% (13/29) met the guideline of 6.4 WTE. In 2010 the revised PICS standards introduced a guideline of 7.01 WTE qualified nurses per bed and in November 2013 only 12% (4/33) of organisations submitting data in the United Kingdom and Ireland met this guideline, whilst 18% (6) met the previous guideline of 6.4 WTE.

Figure 2 shows that nurse staffing levels have fluctuated over time reflecting both the turnover of staff and possible difficulties in the recruitment of paediatric intensive care nurses, both in terms of numbers, knowledge and skills. International review also shows that the number of nurses required to staff one paediatric intensive care bed is lower than the current PICS Standard for WTE nurses per bed in the United Kingdom.

CLINICIAN'S COMMENTARY

The annual PICANet staffing survey has provided important snapshots of information on our workforce over the years.

A few key points emerge from the data that should be considered in the design of the workforce for the future; particularly in this world of financial austerity and lowered public confidence following the Francis report [5].

Firstly, over the last 10 years, there has been some investment in senior nursing leadership with the number of band 8-9 posts trebling to total 25 across the UK. However, the proportion remains small, at only 1.3% of the nursing workforce. The principle leadership roles of the nurses in this band (advanced clinical practice or managerial) do not form part of this report. The numbers of band 7 nurses has decreased despite increases in bed and overall nurse numbers. The combined ratio of the senior bands (7, 8 & 9) has remained roughly static over 10 years (11.7% in 2004 & 11.2% in 2013). This suggests that advanced nurse practitioners are still a rarity. The band 5 and 6 nursing pool has expanded, however the extent of expansion is below that of bed numbers.

The majority of units have not, and still do not reach the PICS national standards for nursing staff numbers in the last 10 years. This trend has worsened over time, with only 4 units achieving the standards in 2013. From this data alone, it is difficult to extrapolate the extent of, and where, the problems may lie. Questions remain to be answered e.g. Are there too few trained nurses available to fill vacant posts? Is there too little emphasis on training and nurse career development? Is the retention of staff poor and what are the factors driving this?

Importantly, PICS nursing standards do not currently include staff numbers to improve patient safety (nurse in charge) or flexibility (nurse in charge, runner) and there is no time commitment to nurse training or education.

It is difficult to understand how we have managed to improve PICU mortality over the last 10 years in the face of such an on-going shortfall in the nursing workforce; and the answers are complex.

PICU mortality may not be the best quality indicator to determine the effect of the nurse workforce on PICU outcomes. Perhaps related outcomes need to be evaluated in the future, such as accidental extubation rates, high grade pressure sores, staff retention rates, nurse progression rates. The limitations of PICU mortality as a quality indicator of our service have been discussed in several previous annual report clinical commentaries.

Much of the workforce shortfall is made up with regular reliance on agency staff, many of whom may also be substantive appointments working additional duty hours. This has implications for staff stress, potential burnout and staff retention. Agency staff that are not substantive run the risk of missing training and career development opportunities and this will affect the quality of the service we deliver. Essentially we are over-reliant on the goodwill of our nursing workforce to bridge the staffing gap and this should be addressed.

The future

In these times of austerity our valuable Critical Care nursing workforce needs to be protected. The future challenge for PICU nursing includes developing high quality nursing outcome measures that are meaningful and accurate. This will in turn inform decisions about nurse-patient ratios in PICU. PICS nurse leaders should direct their efforts to attract, keep, support, train and develop our nurses over a life-time's career. We need to invest in training, education and the development of career pathways. We need to better understand factors contributing to loss of job satisfaction, work related stress and high turnover rates in order to combat these problems.

The potential shortage of experienced nurses over the next decade is of significant concern for the NHS. Those retiring have years of experience and the solution isn't as simple as replacing nurses who retire, with new graduates. PIC nurse leaders need to grow and develop the workforce at all levels to ensure we have enough senior nurses with adequate experience for the future.

Critical care is an innovative and rapidly advancing speciality. Advancing treatment methods and technologies mean that the critical care nurse of the future must have the initiative and support to maintain evidence based practice standards and develop skills to manage evolving technologies. Nurse leaders should progress initiatives to develop advanced clinical practice in both new technologies and in the assumption of medical roles.

Lastly, international recruitment initiatives could be considered. These would bring experience and expertise of qualified nurses with children's critical care experience from America, Canada, New Zealand and Australia. This is a rarity in our speciality and to be able to access these ready available skills can only be in the best interests of the children we care for. The clinical leaders of PICU and the Nursing and Midwifery Council should advocate and lobby for specialist services like PICU to be put back on the UK Border Agency Shortlist Occupation list.

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STANDARDISED MORTALITY RATIOS – ILLUSTRATING WHY RANKING ALONE CANNOT GIVE A FULL PICTURE OF A DECADE OF UNIT PERFORMANCE

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Background

Since the first PICANet annual report was published in 2004 standard mortality ratios (SMRs) have been presented by unit together with funnel plots that provide a graphical means of identifying PICUs that have higher or lower than expected risk adjusted mortality outside specified control limits [1, 2].

A previous analysis of ranking and league tables for mortality in neonatal intensive care units found that confidence intervals often substantially overlapped, and the position of individual units in the league tables varied markedly over the years, largely due to random variation in the data [3]. Natural variability can also lead to difficulties in interpreting data presented only as point estimates or league tables [4].

In view of these caveats attached to the interpretation of SMRs, PICANet have used funnel plots as their control limits allow us to account for differences in the number of admissions between PICUs and provide a graphical means of comparison that does not impose any concept of 'ranking' or league tables. The SMRs of larger PICUs are bound by narrower limits as larger numbers mean that we are more confident that the outcome measure is not attributable to chance. Similarly, smaller PICUs have wider limits.

With ever-increasing focus on performance and the production of 'quality dashboards' that will include a single summary assessment of PICU SMRs, we thought it was appropriate to revisit the issue of ranking institutional SMRs by looking at a decade of PICANet data and discussing the limitations of this approach and other issues relating to the calculation and interpretation of SMRs.

Methods

For each annual report published from 2004 to 2013 the SMR for the most recent year for each unit was extracted from the report. SMRs were compared from the time of reporting and were not recalculated using recalibrated coefficients. If SMRs were reported adjusted for both PIM and PIM2 (from 2006 onwards) the PIM2 adjusted SMRs were used for comparison.

To compare changes in ranking over time and to illustrate how variation in ranking position can take place over several years, several measures were compared. The point estimate and 95% confidence intervals for the SMRs were plotted alongside a summary of the ranks across years for each unit. As the number of units changed across years different rankings have occurred. To allow for this, methods can be used which position each ranking between 0 and 1; Hazen's rule was used to calculate this value for each year for each unit contributing that year, this just converts the rank to a percentage to allow for the differing number of units included each year in the rankings. The closer the Hazen value is to zero the higher the rank in that year's SMR tables i.e. the lower the SMR [5, 6].

SMRs for each unit for each year between 2003 and 2012 are presented in Figure 1. The results show how most SMR confidence intervals in the same year overlap and also the variability in the size of confidence intervals relating to the different PICUs due to the large variation in the number of patients admitted. It is clear from this figure that the rank of each PICU changes year to year.

Figure 2a illustrates the same variability using the rankings of each PICU over the reporting period in a different format. This busy graph clearly illustrates the rankings are highly variable and not always predictive of performance the year after e.g. a high ranking one year does not always lead to a high ranking the year after. To show some units in more detail five units were chosen who had ten years of SMR ranking data available and their rankings across the years are shown in Figure 2b. Table 1 presents a summary of the variation in rankings across the ten years for each unit; this again shows how much variation occurs in how units are positioned across a decade of admissions data.

Figure 1. Reported SMRs by PICU by year

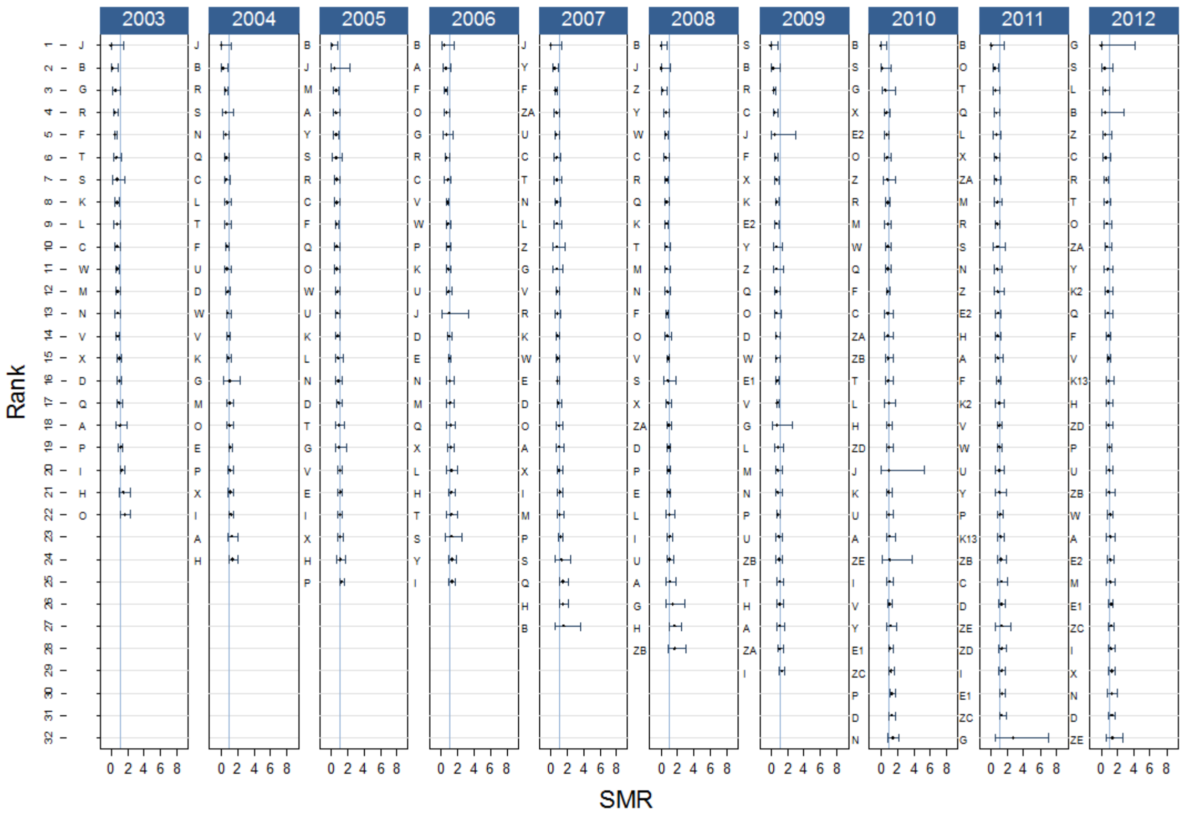

Figure 2a. The ranking for each PICU over the ten year period

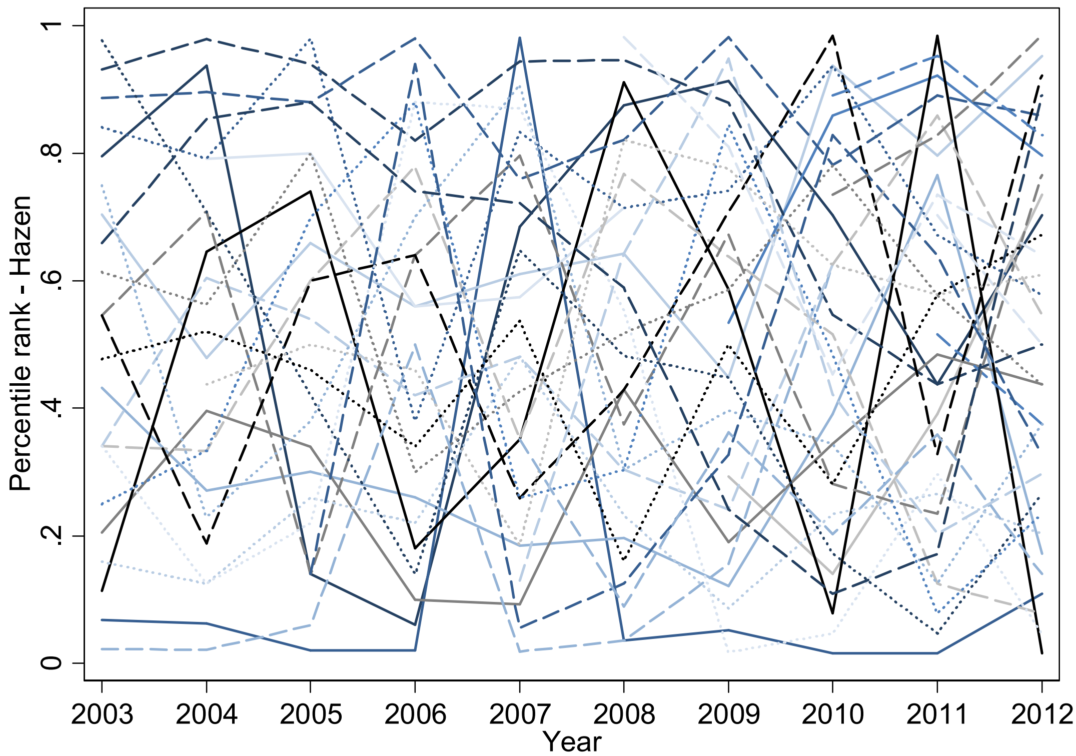

Figure 2b. The ranking for each unit over the ten year period for five of the units who contributed over the full PICANet period

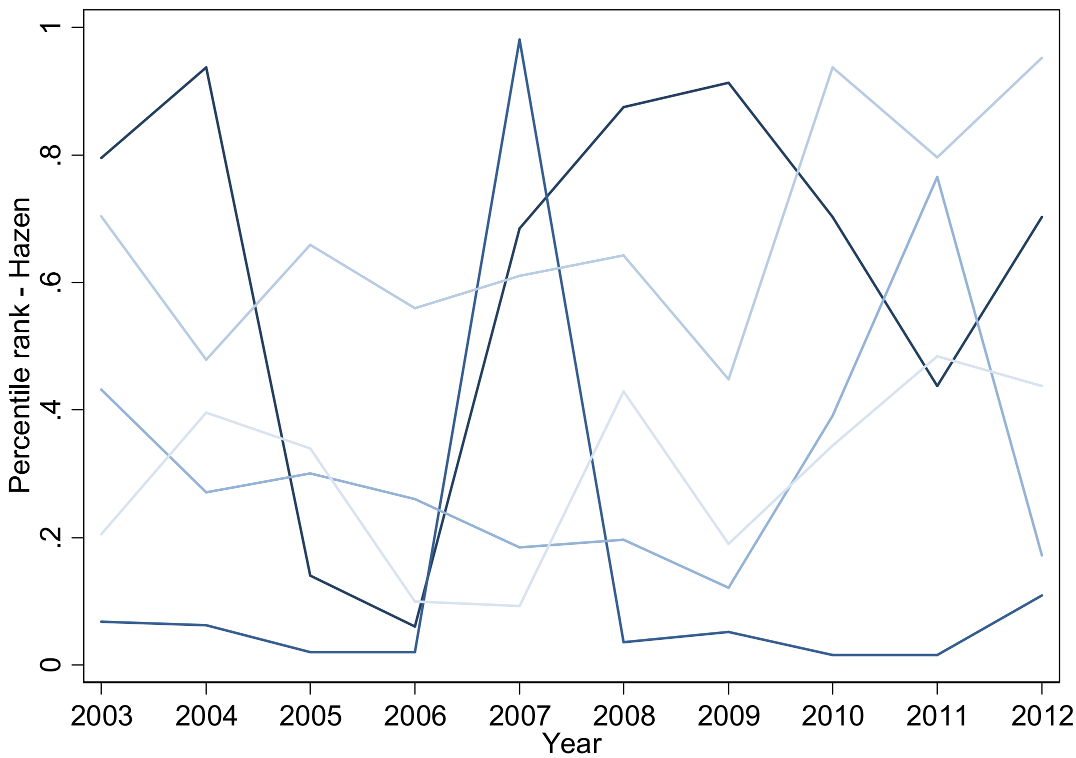

Table 1. Summary of ranking of SMRs and its variability for each unit

Organisation	Number of SMRs	Summary of ranking				
		Minimum	25th Percentile	Median	75th Percentile	Maximum
A	10	2.00	14.50	21.00	23.00	27.00
B	10	1.00	1.00	1.75	2.00	27.00
C	10	4.00	6.00	7.00	10.00	25.00
D	10	12.00	14.50	17.00	26.00	31.00
E	5	14.50	16.00	19.50	20.50	20.50
E1	4	16.00	21.00	27.00	29.00	30.00
E2	4	5.00	7.00	11.00	18.50	24.00
F	10	3.00	5.00	9.50	12.50	16.00
G	10	1.00	3.00	13.00	19.00	32.00
H	10	14.50	18.00	22.50	26.00	27.00
I	10	20.00	22.00	24.25	28.00	29.00
J	8	1.00	1.00	1.75	9.00	20.50
K	8	7.50	8.50	12.25	14.50	20.50
KI1K3	2	16.50	16.50	19.75	23.00	23.00
K2	2	12.50	12.50	14.75	17.00	17.00
L	10	3.00	8.00	12.75	19.00	22.00
M	10	4.00	9.50	14.50	20.00	25.00
N	10	5.00	11.00	14.00	21.00	32.00
O	10	2.00	6.00	12.25	17.50	22.00
P	10	10.00	19.00	21.25	23.00	30.50
Q	10	4.50	9.00	11.75	17.00	25.00
R	10	3.00	4.00	7.00	8.00	13.50
S	10	1.00	2.00	7.00	16.00	24.00
T	10	3.00	7.50	8.75	18.00	25.00
U	9	5.50	12.00	19.00	20.50	23.50
V	10	8.00	14.00	14.75	19.00	25.50
W	10	5.00	9.50	12.50	15.00	22.00
X	10	4.00	7.50	18.00	21.00	29.00
Y	8	2.00	4.00	10.50	22.50	27.00
Z	6	3.00	5.00	8.50	11.00	12.00
ZA	6	4.00	7.00	12.00	18.50	28.00
ZB	5	15.00	21.00	24.00	24.00	28.00
ZC	3	27.00	27.00	29.00	31.00	31.00
ZD	3	18.00	18.00	20.50	28.00	28.00
ZE	3	24.00	24.00	27.00	32.00	32.00

Discussion

Our findings from 10 years of PICANet data suggest that ranking and league tables alone are not a good method of assessing variation in institutional performance. The position of most PICUs varied annually in the rankings giving little information underlying performance but reflecting the random variability about a mean mortality rate. Control charts and funnel plots are used to allow comparison of units within a particular time period. Methods such as CUSUM plots or RSPRT plots [7] can provide an assessment of individual performance across time (almost in real time) but are subject to a separate set of problems related to their underlying statistics and they are not always clearly displayed in the literature [8].

Ranking is not the only issue to have caused controversy when considering institutional comparisons in many health disciplines. Comparing institutional performance is always difficult especially in paediatric intensive care where case-mix has a major influence on mortality rates within units and risk adjustment is required [9]. Mortality rates and the factors that influence them can change relatively quickly over time due to changes in treatments and other advances which may change the main factors which influence mortality which may not be included in previous case-mix adjustment models such as PIM as can be seen through the refinements from PIM to PIM2 and PIM3 [10]. Using the outcome of in-hospital mortality is known to have related biases, something PICANet is investigating by exploring 30-day mortality [11, 12]. PICANet is developing further outcomes for performance measurement as an alternative to mortality including emergency readmissions within 48 hours [13] and ventilator free days [14].

CLINICIAN'S COMMENTARY

In common with most Paediatric Intensive Care Services, the one in which I work provides feedback for the various hospitals from which it receives patients. At one of the first meetings I chaired, soon after PICANet data had been published for the first time, a consultant paediatrician offered congratulations, and invited me to comment on the unit in which I worked being 'close to the top of the PICANet league table'. It was very tempting to accept humbly, and to bask in the admiring smiles of the audience. Instead I re-phrased, saying that I was 'delighted that our service was performing within the expected control limits of the mortality risk-adjustment model in a manner comparable to our peers'. The smiles in the audience were now more perplexed, and at our coffee break one of the community paediatricians present asked me lots of questions about how many friends I had, and whether I liked collecting things.

For those of us involved with PICANet for the last decade, one of the important features of its reports is the presentation of the risk-adjusted mortality outcomes in the graphical form of control charts, rather than alternatives which may have encouraged creation of league tables. Even using control charts, I can still remember being asked where my own unit came in the league table by clinical and managerial colleagues, but over the years all clinicians, and in my experience, most other stakeholders have stopped asking this question, as they recognise the purpose of this form of publication is to assist 'quality control' in identifying outliers (at either the positive or negative end) for more detailed analysis. When outliers are identified, it is often because of errors in data collection rather than a true variation in outcome.

There is still a great public, political and media appetite for league tables, as demonstrated when school exam results are published, and in the world of healthcare when hospital mortality statistics are published. League tables are easily understood but are open to misinterpretation. These tables seem to tap into a belief that there is always a hierarchy of performance within a group of institutions. The underlying assumption in compiling league tables is that there are differences in performance between institutions. Using 'control charts' instead starts with the premise that all institutions in the 'system' perform at a similar level, but that there will be special cause variation in performance between them within control limits [15]. When an institution's performance falls outside the control limits, it indicates that the variation in performance is beyond that predicted for expected variation – and without further analysis it says nothing about whether the variation in performance is real.

This analysis of PICANet data supports the use of control charts as a responsible way of representing this data. It is clear that variation in any league table ranking is just as striking in the PICUs across the United Kingdom as it was in the analysis of Scottish NICU mortality data in the 1990s [3].

It is important that PICANet try and develop other outcome measures beyond mortality, and equally important that any data produced is presented in the same manner to avoid misrepresentation. In the years when the mortality outcome, re-admission or ventilator free days data suggest that I am working at a top of the table unit, I will continue to answer in the manner as the first paragraph – as I will in the years where I may have to defend allegations of 'relegation form'.

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NOCA National Office of Clinical Audit

Paediatric Intensive Care Society

HQIP Healthcare Quality Improvement Partnership