

BMJ Open Quality Introducing NICE guidelines for intravenous fluid therapy into a district general hospital

Marcia McDougall,¹ Bruce Guthrie ,² Arthur Doyle,³ Alan Timmins,⁴ Meghan Bateson,⁵ Emily Ridley,⁶ Gordon Drummond ,⁷ Thenmalar Vadiveloo⁸

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¹Department of Anaesthesia, Victoria Hospital, Kirkcaldy, UK

²University of Edinburgh, Community Health Sciences, Edinburgh, UK

³Renal Unit, Queen Elizabeth University Hospital, Glasgow, UK

⁴Pharmacy Department, Victoria Hospital, Kirkcaldy, UK

⁵Institute of Healthcare Policy and Practice, University of the West of Scotland, Blantyre, UK

⁶Anaesthesia, Victoria Hospital, Kirkcaldy, UK

⁷Edinburgh Medical School, The University of Edinburgh, Edinburgh, UK

⁸Health Services Research Unit, School of Medical Sciences, University of Aberdeen, Aberdeen, UK

Correspondence to

Dr Gordon Drummond;
g.b.drummond@ed.ac.uk

ABSTRACT

Background National Institute for Health and Care Excellence (NICE) guidelines on intravenous fluid prescribing for adults in hospital, issued in 2013, advised less use of 0.9% sodium chloride than current practice, provided a logical system for prescribing and suggested further study of electrolyte abnormalities.

Aims To describe the steps taken to establish and monitor guideline introduction and to assess effects on clinical biochemistry results, in a general hospital setting.

Methods We used established principles of change to modify education, teaching, record keeping and audit throughout the hospital, changed the availability of intravenous fluid preparations in the wards and monitored the use of intravenous fluids. We anonymously linked local clinical chemistry records to nationally available patient records (NHS Scotland SMR01). We chose specified medical emergencies, and major emergency and elective general and orthopaedic surgery, where management would require intravenous fluids, for a two-phase cross-sectional study between 2007 and 2017, spanning the change in prescribing. Primary outcomes were abnormal bicarbonate, sodium, potassium and incidence of acute kidney injury (AKI), and secondary outcomes were mortality and length of stay.

Results Over the study period, sodium chloride 0.9% use decreased by 75%, and overall intravenous fluid use decreased from 0.65 to 0.40 L/occupied bed day. The incidence of acidosis decreased from 7.4% to 4.8% of all admissions (difference -2.7%, 95% CI -2.1 to -3.0). No important changes in other electrolytes were noted; in particular, plasma sodium values showed no adverse effects. Stage 1 AKI increased from 6.7% to 9.0% (difference 2.3%, 95% CI 1.6 to 3.0), but other causes for this cannot be excluded. Mortality and length of stay showed no adverse effects.

Conclusions and implications Effective implementation of the guidelines required substantial time, effort and resource. NICE suggestions of fluid types for maintenance appear appropriate, but prescribed volumes continue to require careful clinical judgement.

INTRODUCTION

Intravenous fluid therapy has been common for almost a century, yet only recently has attention been paid to the quality of this clinical practice. In the UK, teaching material on intravenous fluid therapy is inadequate,¹

the topic is poorly taught,² intravenous fluids are poorly prescribed³ and hospital systems for supervising, prescribing, recording and managing fluid balance are poor.⁴⁻⁸

Concerns over fluid management⁹ led to the introduction of a UK national guideline (NICE, CG 174) aiming to improve intravenous therapy. Recommendations included balanced electrolyte solutions for most types of volume replacement, and that maintenance fluid should provide 1 mmol sodium/kg daily, representing a pronounced move away from previous 'saline heavy' regimens. Systematic studies of maintenance fluid therapy in adults are rare.¹⁰ Although hyponatraemia has been a concern with low-sodium fluids,¹¹ evidence for this in adults is sparse.

Between 2009 and 2010, audits in NHS Fife hospitals had shown patterns of prescribing similar to those causing national concern. To improve this, we set up a teaching programme, developed local guidelines (first using a national consensus, British Consensus Guidelines on Intravenous Fluid Therapy for Adult Surgical Patients (GIFTASUP),¹² and later the NICE guidelines¹³) and redesigned prescription and fluid balance charts. In 2012, we introduced guidelines very similar to those later published by NICE. We suggested, for usual use, a balanced electrolyte solution such as Plasma-Lyte 148 for volume replacement, and sodium chloride 0.18% and glucose 4% for maintenance (see guidance leaflet in online supplemental file). Some critics suggested the NICE guidelines would cause electrolyte disturbances, particularly hyponatraemia.¹⁴ We therefore used linked NHS databases to examine electrolyte abnormalities developing in hospital patients, before and after changing intravenous fluid prescribing, using the RECORD protocol.¹⁵ Secondary outcomes were length of stay and 30-day mortality.

AIMS

To describe the process required to implement the NICE guidelines on intravenous

fluids and assess, using routinely recorded data, the effects on clinical chemistry, particularly the suggested risk of hyponatraemia.

METHODS

Guideline introduction

We applied Kotter's eight principles of quality improvement¹⁶ and added a further national aim.

1. Create—establish urgency for change. Between 2009 and 2010, our hospital audits confirmed that patients often received too much or too little fluid volume, too much sodium and too little potassium. Education of prescribers was limited and fluid balance charts were poorly completed. These audits and findings from the NCEPOD report of 1999¹⁷ were presented to various professional groups within the organisation (surgeons, obstetricians, physicians, intensivists and anaesthetists) and all agreed that practice needed to improve.
2. Form—establish a guiding coalition. We established a planning group (Fife IV Fluid Prescription Group) comprising an anaesthetist, renal physician, pharmacist, dietitian, clinical chemist, senior nurse, general surgeon and an orthogeriatrician.
3. Develop a strategy. Education and better prescribing and recording processes were needed. A programme of education on fluid balance and on the management and prescribing of intravenous fluids was set up for senior and junior doctors, non-medical prescribers and nursing staff. The group wrote guidelines (section 1 of online supplemental material), first using the GIFTASUP guidelines for surgical patients (adapted in Southampton)¹² and then the NICE guideline.¹³ Our guidelines included general guidance and assessment, the composition of common fluid losses and intravenous fluids and suggested regimens for maintenance, replacement and resuscitation. They only addressed intravenous fluid management for adults. National protocols for diabetic emergencies were retained, and senior advice was mandated for complex obstetric patients, patients with neurotrauma and patients with renal impairment.
4. Enlist. Nursing and medical leaders considered and accepted the guidance. After feedback from hospital consultants (attendings), the guidelines were distributed to all doctors and nurses involved in intravenous therapy and posted on the hospital computer network.
5. Enable. Pharmacists ensured the correct fluids were stocked on the wards and storage areas were reorganised. Education for prescribers and nursing staff continued.
6. Generate goals. Improved procedures were needed to make the changes sustainable. Although the guidance was accepted and widely distributed, prescribers tended to revert to previous habits if a copy of the guideline was not to hand. A key development was to redesign the paperwork, using a double-sided chart, with a 24-hour fluid prescription on one side and a balance

chart on the other. This chart incorporated the guideline principles and safety checks (see section 4 of online supplemental material). To introduce the chart, a quality improvement nurse for fluid management was appointed with funds from the research and development department, and after 8 months of testing on four pilot wards, the chart was implemented throughout the hospital in 2014.

7. Sustain. Use the wins and gains to produce bigger results. The fluid nurse set up resources for reference and education, attended senior nursing meetings to maintain enthusiasm for the changes, held teaching sessions, audited fluid balance and prescription charts and used the results to encourage learning on the wards. An electronic learning module for nurses and prescribers was set up, and teaching was incorporated into junior doctors' induction and subsequent mandatory training programmes. Pharmacy involvement was instrumental in the introduction of litre bags for maintenance fluids and encouraging the use of potassium-containing maintenance fluids. The fluid team is now involved in standardisation and procurement of infusion devices.
8. Institute. Incorporate the changes into the culture of the organisation. The new fluid prescription and balance charts became standard in the hospital. Regular education sessions on fluids were made routine, along with regular presentations on the project at hospital clinical governance meetings. The project is part of the hospital's quality improvement programme. The fluid nurse post is now permanent.
9. Disseminate. A successful quality improvement programme should be extended widely. A national programme began in February 2018 in Scotland, funded by the Scottish Government. It aims to introduce the NICE guidelines into all Scottish hospitals and standardise education across all higher education establishments teaching healthcare professionals. This is a national opportunity to improve patient care, standardise practice and reduce morbidity and mortality. National Clinical leadership is provided by the NHS Fife fluid team.

Study design

We compared biochemical outcomes in patients in specified diagnostic and treatment categories treated in NHS Fife, before and after the introduction of fluid guidelines and education to improve fluid prescribing. These guidelines are based on 'Guidelines for Intravenous Fluid Therapy in Adults in Hospital' (NICE CG174¹³). NHS Fife Health Board provides acute medical and surgical care to a population of 372 000 residents in urban and rural areas. Hepatic, cardiothoracic and neurosurgery are not provided. Before January 2012, acute care was provided in two district general hospitals, and then centralised to a single site with 458 beds. Patient management teams remained unchanged in experience and composition, before and after the hospital changes. All assays were

with the same equipment. The analysers were replaced in 2015, but the method used for sodium assay remained the same. Verification data at analyser changeover found no bias between the two devices.

Study population

This was an observational, epidemiological study, for which the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist would be appropriate.¹⁸ In addition, because we linked observational routinely collected health data, we applied the relevant extension of the STROBE checklist, RECORD.¹⁵ We used the general acute inpatient and day case—Scottish Morbidity Record (SMR01) dataset.¹⁹ This gives age, gender, date of admission, diagnostic category and date of discharge as well as mortality data if appropriate. We used the national unique patient identifier (the Community Health Index Number) to link anonymised selected records from these data with NHS Fife biochemistry laboratory records. We studied adults aged 18 years and over, admitted to hospital for 4 or more days, with conditions where intravenous fluid use would be routine or very common, from the third quarter of 2007 to the first quarter of 2017 inclusive. We chose patients with procedures classified as follows:

1. Major emergency and elective general surgery.
2. Major emergency and elective orthopaedic surgery.
3. Emergency medical admissions with diagnostic codes for sepsis, pneumonia, gastroenteritis and gastrointestinal bleeding.

We only analysed data from patients who had initial normal values for that electrolyte on admission. Analysis of creatinine values is described below. We excluded patients with a diagnosis of end-stage renal failure.

An adverse outcome was defined as a new abnormal biochemical value from day 3 of an admission, in a patient with a normal value on days 1 and 2. If no blood test was done on days 1 and 2 (eg, in elective surgery where blood is taken at assessment before admission), then a normal value in the preceding year was accepted.

Acidosis was defined as a serum bicarbonate concentration of <23 mmol/L. Hypernatraemia was defined as a serum sodium >155 mmol/L and hyponatraemia as <126 mmol/L. We chose this latter value as concentrations from 126 to 135 mmol/L are rarely of clinical significance. Hypokalaemia was defined as serum potassium <3.1 mmol/L and hyperkalaemia as >5.4 mmol/L.

Acute kidney injury (AKI) was defined using the KDIGO (Kidney Disease: Improving Global Guidelines) definition²⁰ of three stages based on changes in serum creatinine:

- ▶ Stage 1: either an increase of ≥ 26.5 $\mu\text{mol/L}$ over 48 hours or an increase to 1.5–1.9 times baseline.
- ▶ Stage 2: an increase to 2.0–2.9 times baseline.
- ▶ Stage 3: either an increase to >3 times baseline or an increase to >354 $\mu\text{mol/L}$.

Baseline renal function was defined using either the median of creatinine values from 7 to 364 days before

admission or the least value in the 7 days before admission, whichever was the lesser. Since AKI evaluation required 1 year of data before the index admission, AKI outcomes could only be measured from quarter three in 2008 to quarter one in 2017.

Patient and public involvement

Because this study was entirely retrospective, no patient involvement was sought. Audits of trainee doctors were voluntary.

Statistical analysis

We studied the time periods before and after the end of the second quarter of 2012, when the guideline was introduced. The primary outcome of the study was any change in frequency of abnormal values of plasma electrolytes and creatinine developing after admission to hospital, comparing periods before and after the guideline introduction. Hospital length of stay and 30-day mortality were only used as secondary outcomes because these measures are subject to confounding by multiple factors. Since the study was retrospective, we chose to only formally analyse two clinical subgroups, emergencies and elective surgery.

To compare frequencies, we used the 95% CI for the difference between two independent proportions, with a continuity correction.²¹ We assumed that these small frequencies of binomial categories followed a Poisson distribution, where CIs are not symmetrical. All calculations were done using Vassar Stats,²² and the methods used are those of Zar.²³ Two-tailed p values are stated if these were less than 0.05, which may aid interpretation. No adjustments were made for multiple comparisons.

RESULTS

We studied 32 672 admissions overall: 15 639 before and 17 033 after guideline introduction. Of the total studied, 34% were medical emergencies, 18% were general surgical emergencies, 11% were general surgical electives, 24% were orthopaedic emergencies and 13% were orthopaedic electives. The number of patients in whom the incidence of AKI was studied was fewer (23 403), because a diagnosis of AKI requires a preceding creatinine value. Other details of the study populations are given in online supplemental file. Subgroup totals may differ because of the different criteria for record selection.

Effects of the guidelines

Changes in intravenous fluid use over time, including the study period, are shown in figure 1. The use of sodium chloride 0.9% decreased from the start of fluid education (line A). After prescribing guidelines were introduced (line B, the primary time chosen as intervention), sodium chloride 0.9% use decreased further and more of the balanced electrolyte solution was used. The use of potassium supplements in sodium chloride 0.18% and glucose 4% was initially limited, but increased in 2017 (lower panel), when greater use of potassium supplements was encouraged. The total fluid use, expressed in

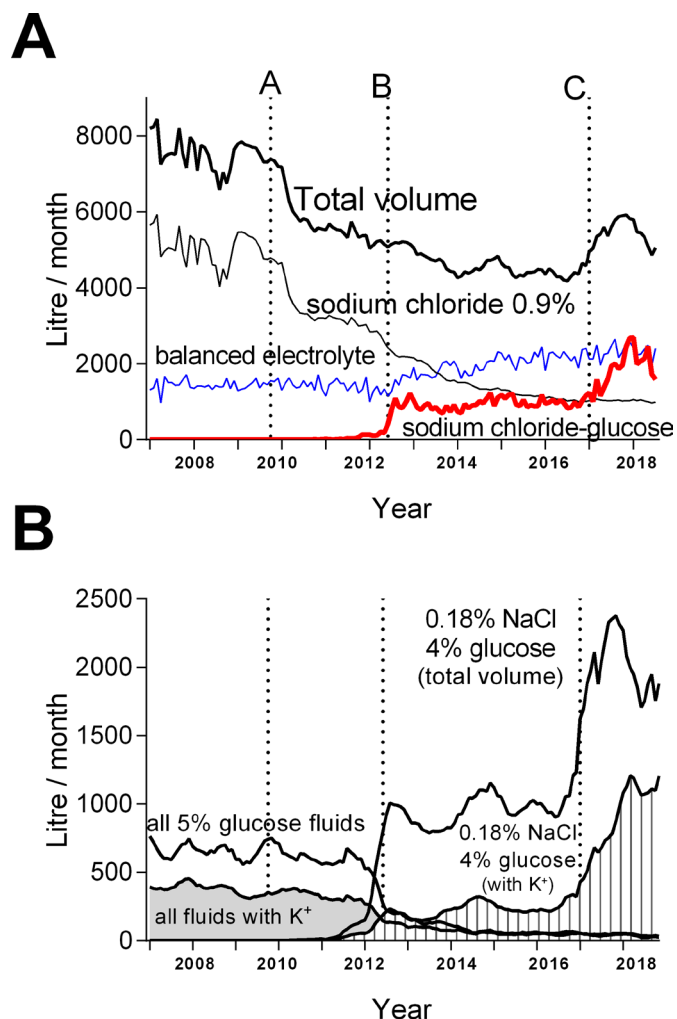


Figure 1 Monthly fluid use over the study period. (A) Changing use of total fluid, 0.9% sodium chloride, balanced electrolyte solutions (Hartmann's solution and Plasma-Lyte) and the introduction of 0.18% sodium chloride and 4% glucose as a maintenance fluid. (B) Changes in the pattern of maintenance fluid use and potassium supplements over the same period. Before time mark B, all fluids containing potassium are shown, that is, 0.9% sodium chloride with potassium and 5% glucose with potassium. Note the different scale for fluid volume. Time marks apply to both panels and indicate: A: start of fluid education, B: Guidelines introduced and C: sustained campaign to encourage 0.18% sodium chloride and 4% glucose solutions with potassium.

litre/occupied bed day, gradually and linearly decreased from 0.65 in 2007 to 0.4 in 2017.

Biochemical outcomes

Our findings are summarised in table 1 and presented first as data for the entire study population and then separately for emergency and elective patient subgroups.

Acidosis

The incidence of metabolic acidosis before the guidelines was 7.4%. After the guidelines, it decreased to 4.8% (a decrease of 2.7%; 95% CI 2.1. to 3.2, $p < 0.0002$), with an

association between the use of sodium chloride 0.9% and the incidence of acidosis (figure 2).

Sodium and potassium values

The incidence of abnormal sodium and potassium values was small. Hyponatraemia did not increase after guideline introduction. There was an overall increase in hyperkalaemia from 1.6% to 2.3% (an increase of 0.7%; 95% CI 0.4 to 1.0; $p < 0.0002$) (table 1). However, there was no clear association with the greater use of potassium supplements, which is shown in figure 1B, after line C.

Acute kidney injury

The incidence of AKI in the entire population increased after guideline introduction. Considering the emergency and elective patients separately, the increase was only seen in emergency patients.

Length of stay and mortality

Data were only available from 2008 to 2016 for length of stay and 30-day mortality. Length of stay differed substantially between the groups, being longest in medical emergency patients. Medical emergency patients also showed the greatest mortality at 30 days after admission. Mortality was small in the other groups. Neither length of stay nor mortality changed after the guideline introduction.

DISCUSSION

Implementation of guidelines

Examples of formulaic transliteration of the NICE guidelines into hospital policy documents, followed by ticked boxes, are easily found, evidence of deliberate, systematic, coordinated and persistent changes in practice is rare.²⁴

We present an account of the process of implementing a guideline such as NICE 174 in an NHS region and a means of assessing outcome. The gradual time course and the progressive changes involved in the process can be understood from figure 1. Pharmacy data proved invaluable in tracking progress, and have been useful since at the ward level, to allow education to be directed appropriately. Effective change is impeded by junior doctors (residents) moving from other centres, often having established poor prescribing habits, and the cohort of more senior doctors who continue as they have done before, both these groups require sustained education. The ubiquity of a guideline booklet is vital, a dedicated intravenous fluids nurse invaluable, and a multidisciplinary team provides an essential foundation for what is a long-term project.

National implementation

In February 2018, a National Intravenous Fluid Improvement Programme was set up by the Scottish Government and the Fife fluid team. All NHS boards in Scotland are working to improve fluid prescription and balance and provide information on fluid use.²⁵ Uniform teaching in medical and nursing schools should reduce variation in prescribing, simplify the task of prescribing for junior staff and emphasise the importance of good fluid balance recording. Figure 3

contrasts intravenous fluid use for different health boards in Scotland for the years 2017 and 2018.²⁶ The effect of guideline use is evident, Fife used the least sodium chloride 0.9% and greatest proportion of sodium chloride 0.18% and glucose 4%.

Study advantages

We could determine the effects of a substantial change in hospital practice, in a large population from a single geographic region, admitted to a general hospital over a ten-year period. We used a reliable well-established data source that is regularly audited,²⁷ and we used standardised reporting guidelines.¹⁵ The study size was sufficient to detect small changes in the frequency of abnormalities, for

Table 1 Clinical measures before and after guideline introduction

Feature	Before guidelines				After guidelines			
	Case numbers	Cases	%	5%–95% CI	Case numbers	Cases	%	5%–95% CI
Entire population								
Any abnormality	15 639	2248	14.4	13.8 to 14.9	17 033	2037	12.0	11.5 to 12.5
Acidosis		1164	7.4	7.0 to 7.9		813	4.8*	4.5 to 5.1
Hyponatraemia		155	1.0	1.0 to 1.3		185	1.1	0.9 to 1.3
Hypernatraemia		146	0.9	0.9 to 1.3		112	0.7	0.7 to 1.0
Hypokalaemia		537	3.4	3.6 to 4.3		542	3.2	3.6 to 4.3
Hyperkalaemia		246	1.6	1.6 to 2.1		385	2.3*	2.6 to 3.2
Mortality	13 592	1311	9.6	9.2 to 10.0	13 144	1261	9.6	9.1 to 10.1
Length of stay (mean)		7.7				9.2		
AKI	10 541				12 862			
Stage 1		707	6.7	6.2 to 7.2		1160	9.0*	8.5 to 9.5
Stage 2		151	1.4	1.2 to 1.7		308	2.4*	2.1 to 2.7
Stage 3		151	1.4	1.2 to 1.7		256	2.0	1.8 to 2.3
Emergency patients (medical, general and orthopaedic surgery)								
Any abnormality	10 701	1867	17.4	16.7 to 18.2	12 757	1690	13.2	12.7 to 13.8
Acidosis		923	8.6	8.1 to 9.2		653	5.1	4.8 to 5.5
Hyponatraemia		126	1.2	1 to 1.4		132	1.0	0.8 to 1.2
Hypernatraemia		143	1.3	1.1 to 1.6		110	0.9	0.7 to 1.0
Hypokalaemia		487	4.6	4.2 to 5.0		510	4.0	3.7 to 4.4
Hyperkalaemia		188	1.8	1.5 to 2.0		285	2.2	2.0 to 2.5
Mortality	8654	1288	14.9	14.1 to 15.6	8868	1234	13.9	13.2 to 14.7
Length of stay (mean)		8.9				7.8		
AKI	6873				8868			
Stage 1		514	7.5	6.9 to 8.1		807	9.1	8.5 to 9.7
Stage 2		116	1.7	1.4 to 2.0		209	2.4	2.1 to 2.7
Stage 3		146	2.1	1.8 to 2.5		223	2.5	2.2 to 2.9
Elective patients (general and orthopaedic surgery)								
Any abnormality	4938	381	7.7	7.0 to 8.5	4276	347	8.1	7.3 to 9.0
Acidosis		241	4.9	4.3 to 5.5		160	3.7	3.2 to 4.4
Hyponatraemia		29	0.1	0 to 0.1		53	1.2	0.9 to 1.6
Hypernatraemia		3	0.0			2	0.0	0 to 0.2
Hypokalaemia		50	1.0	0.8 to 1.3		32	0.7	0.5 to 1.1
Hyperkalaemia		58	1.2	1.0 to 1.5		100	2.3	1.9 to 2.8
Mortality	4938	23	0.5	0.3 to 0.7	4276	27	0.6	0.4 to 0.9
Length of stay (mean)		4.3				4.4		
AKI	3668				3994			
Stage 1		193	5.3	4.6 to 6.0		353	4.0	3.6 to 4.4
Stage 2		35	0.9	0.6 to 1.3		99	1.1	0.9 to 1.4
Stage 3		5	0.1	0 to 0.3		33	0.4	0.3 to 0.5

*For the entire population, significant change, $p < 0.0002$. Statistical analysis of differences in the subgroups was not carried out.
AKI, acute kidney injury.

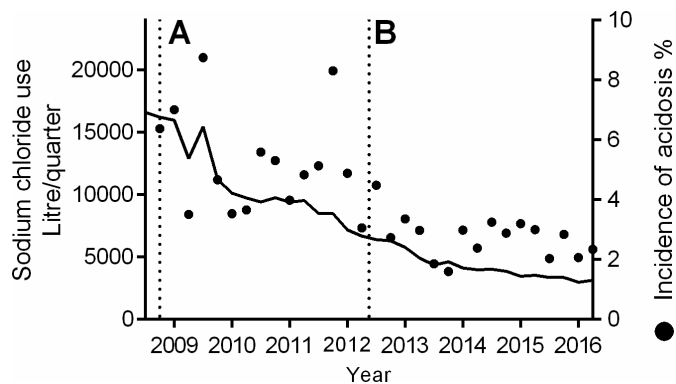


Figure 2 Association between the use of 0.9% sodium chloride (solid line) and the quarterly incidence of acidosis (filled circles), over the early study period. Time marks indicate: A: start of fluid education and B: guidelines introduced.

example, an increase of 0.3% more than the 'before' incidence of hyponatraemia would be significant ($p=0.05$), if a null hypothesis was tested.

To generate and sustain changes in fluid prescribing, we had the advantage of working in a medium-sized health board (sixth in rank size in Scotland), where communication and co-operation among specialties were straightforward. We provided education and generated behavioural change using a team drawn from a relevant range of specialties. Consistent and persistent teaching and review were required to change prescribing habits, and education had to be reinforced, particularly about prescribing potassium. If we had arbitrarily excluded

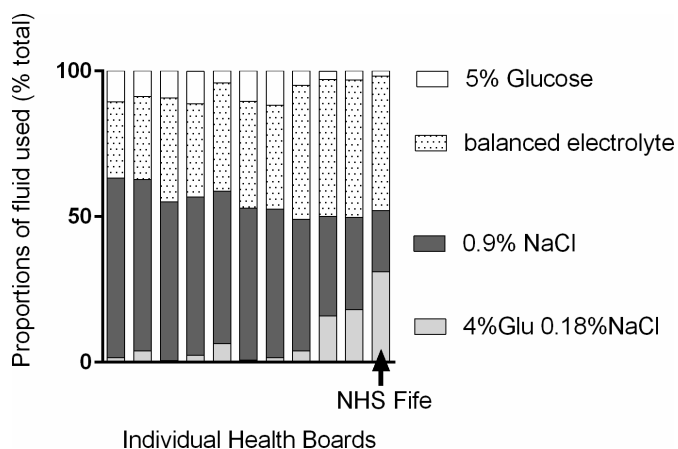


Figure 3 Proportional usage of intravenous crystalloid fluids in Scottish health boards, ranked in decreasing order of proportional use of 0.9% sodium chloride, for the financial years 2017 and 2018. The effect of implementing the NICE guidelines is clear, comparing NHS Fife to the pattern of use in other health boards. Note the greater use of 0.18% sodium chloride and 4% glucose, the limited use of 5% glucose and a smaller proportion of use of 0.9% sodium chloride, indicating maintenance prescribing based on the NICE guidelines. The two columns adjacent to NHS Fife show the start of similar prescribing in these hospital boards. NHS, National Health Service; NICE, National Institute for Health and Care Excellence.

an interim 'changeover' period, a greater difference between 'before' and 'after' might have been evident. However, this would have reduced the sample sizes and was not defined a priori.

Study limitations

We measured overall fluid use, not the actual fluids given to the selected study patients. However, we believe we selected most of the patients given intravenous fluids, so overall use should be a good indication of the fluids received by the study group. Local audits in 2019 showed that junior doctors appreciated consistent teaching, were confident in fluid prescribing²⁸ and were 90% compliant with the guidelines.²⁹

Our study concentrated on how fluid prescribing affected biochemistry results, and was not able to consider other patient factors or outcomes. Although age, gender and social deprivation are available in the SMR01 database, these were not considered to be relevant covariates. Many other possibly relevant factors are not available from SMR01, and we have to assume that features such as frailty, comorbidity, concomitant medication, or surgical techniques would be similar in the before and after groups. Specific and reliable individual records would be required to examine such potential covariates, the most relevant of which might be fluid load in each patient. This study was not designed to examine other relevant outcomes, such as those caused by fluid overload, for example, oedema. A small study of similar changes in fluid prescribing in 2010 showed that oedema and intestinal stasis in surgical patients were less when fluid input was limited. The authors³⁰ noted that a randomised study to show benefit from improved prescribing would entail very substantial resources, in contrast to linking available pre-existing data. Patients admitted with abnormal biochemistry were excluded from analysis, and we cannot extrapolate our findings to patients with pre-existing conditions such as renal or hepatic failure. Such patients are already specified in the guidelines as requiring specialist management.

Our study found little effect on electrolyte abnormalities, suggesting that further studies of this topic are probably not needed. However, an option for further data linking could be to use community pharmacy records, which could allow outcomes to be related to long-term medication, such as anti-hypertensive therapy. We have no current electronic record systems that might link individual patient fluid prescription to clinical outcome measures such as oxygen requirements, which might indicate pulmonary dysfunction.

Specific findings

Effect of guideline implementation

Intravenous fluid use changed substantially over the study period. The use of sodium chloride 0.9% decreased, and this was associated with less metabolic acidosis. Abnormal sodium and potassium values were not frequent, and there were no important changes overall when the guidelines were adopted. The most common abnormality observed was hypokalaemia, which was unaffected by the change in fluid therapy. More recently, since potassium

supplements have been encouraged (see figure 1B), this may have reduced. Hyponatraemia was rare, with an overall incidence of less than 1.5%. However, clear increases in stage 1 AKI were found in the whole study population, and particularly in the emergency subgroup, these findings are discussed below.

Acidosis caused by sodium chloride 0.9% is generally transient,²⁰ but it can be harmful.³¹ We found substantially less acidosis as the use of sodium chloride 0.9% declined (figure 2).

Hyponatraemia

Fluid maintenance regimens with a sodium content of 1 mmol/kg/day, using 0.18% sodium chloride and 4% glucose, have been suggested by some to cause hyponatraemia.^{11 14} The large observed changes in fluid use gave us opportunity to examine this risk. Although some changes were found, these were small. Specifically, the overall incidence of hyponatraemia was 1.0% before and 1.1% after the guidelines and not statistically significantly different. No incidents of harmful hyponatraemia associated with maintenance fluid use were reported in the hospital's incident reporting system from 2010 to 2017 or directly to the clinicians involved in the teaching programme.

Acute kidney injury

Volume replacement therapy with balanced crystalloids has been associated with less AKI than using sodium chloride 0.9%.³² However, we found an overall increase in stage 1 AKI, from 7.5% to 9.1%, and in stage 2 from 1.4% to 2.4%. There was no association with increased mortality or length of stay.

In our study, AKI stage 1 also increased significantly in emergency patients, whereas no increase was noted after elective general surgery. Similar increases in AKI after surgery have been noted before.³³ In Scotland from 2000 and 2016, although a national review of joint replacement procedures showed a slow decrease in surgical complications to less than 1%,³⁴ the incidence of what the review termed 'acute renal failure' increased from 0.3% to 2%. This was attributed to more comorbidity, increased use of nephrotoxic antibiotics and ACE inhibitors and also enhanced recovery regimes, introduced in 2010.³⁵ In this enhanced recovery regime, intravenous fluids were discontinued immediately after elective surgery, and adequate oral intake was expected, this was later recognised to limit fluid intake. When this was appreciated, oral fluid intake after surgery was encouraged, and the national incidence of renal failure decreased.³⁶ In our study, AKI stage 1 also increased significantly in patients admitted with general surgical emergencies, whereas no increase was noted after elective general surgery. Similar findings in patients after elective surgery have already been reported,^{37 38} and attributed to guidance to avoid excessive intravenous fluid administration.

It is possible that excessive fluid administration (before the guidelines were applied) may have concealed renal dysfunction by a dilutional effect on creatinine values. Our education programme emphasises that patients should be

given the right amount of fluid, neither too much nor too little. In NHS Fife, AKI alerts based on creatinine assays were introduced in 2017 to allow prompt action to prevent AKI progression.

SUMMARY

Implementing NICE guidelines for intravenous therapy is no mean task and requires co-ordination and persistence. Implementation in our health board substantially reduced acidosis and did not materially change the incidence of electrolyte abnormalities. We found more stage 1 AKI in patients after elective orthopaedic surgery, but in these patients enhanced recovery management had been introduced at the same time, which until recognised, impaired hydration. Teaching a structured approach to fluid management and limiting fluid choice improve routine prescribing, experience and clinical judgement remain important in prescribing replacement volumes.

Correction notice When first published, this article had changed 'creatinine' to 'creatine' throughout the article. This has now been corrected.

Contributors Conception and study design: MMD, BG, AD and AT. Acquisition, analysis or data interpretation: MMD, BG, AD, AT, MB, ER, GD and TV. Drafting and revision of intellectual content: MMD, BG, AD, AT, MB and GD. MMD is guarantor for the study.

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Competing interests MMD has been a member of advisory panels on intravenous fluids for Baxter Healthcare and has given educational talks on fluid guidelines for Baxter Healthcare and Teva Healthcare.

Patient consent for publication Not applicable.

Ethics approval The study followed local Standard Operational Procedures required by NHS East of Scotland Research Ethics Committee and the relevant Caldicott Guardians (legally responsible for approving use of unconsented NHS patient data). Data analysis followed statutory procedures for anonymised data held in the ISO27001 and NHS Scotland accredited Health Informatics Safe Haven.

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Data availability statement Data are available upon reasonable request. Any researcher can apply for permission to access these raw data: apply to <https://www.dundee.ac.uk/hic/>.

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ORCID iDs

Bruce Guthrie <http://orcid.org/0000-0003-4191-4880>

Gordon Drummond <http://orcid.org/0000-0002-7038-1887>

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