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Review

The pathophysiology of fluid and electrolyte balance in the older adult surgical patient☆

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SUMMARY

Background & aims: Age-related physiological changes predispose even the healthy older adult to fluid and electrolyte abnormalities which can cause morbidity and mortality. The aim of this narrative review is to highlight key aspects of age-related pathophysiological changes that affect fluid and electrolyte balance in older adults and underpin their importance in the perioperative period.
Methods: The Web of Science, MEDLINE, PubMed and Google Scholar databases were searched using key terms for relevant studies published in English on fluid balance in older adults during the 15 years preceding June 2013. Randomised controlled trials and large cohort studies were sought; other studies were used when these were not available. The bibliographies of extracted papers were also searched for relevant articles.
Results: Older adults are susceptible to dehydration and electrolyte abnormalities, with causes ranging from physical disability restricting access to fluid intake to iatrogenic causes including polypharmacy and unmonitored diuretic usage. Renal senescence, as well as physical and mental decline, increase this susceptibility. Older adults are also predisposed to water retention and related electrolyte abnormalities, exacerbated at times of physiological stress. Positive fluid balance has been shown to be an independent risk factor for morbidity and mortality in critically ill patients with acute kidney injury.
Conclusions: Age-related pathophysiological changes in the handling of fluid and electrolytes make older adults undergoing surgery a high-risk group and an understanding of these changes will enable better management of fluid and electrolyte therapy in the older adult.

1. Introduction

The number of people aged 65 years and over has increased significantly across the developed world, a likely result of advances in medical care. Between 1999 to 2000 and 2009 to 2010, there was a 66% rise across England in hospitalization of persons over the age of 75 years.[1] The UK government estimates that the number of people aged 65 years and over will double by the year 2050, with an associated increase in public cost burden.[2]

Older adults are susceptible to dehydration and electrolyte abnormalities, causes of which are multifactorial, ranging from physical disability restricting access to adequate fluid intake to iatrogenic causes including polypharmacy and the unmonitored use of diuretics and other drugs.[3] Physical disability in older adults can limit access to water,[4] whilst incontinence-associated embarrassment may lead older adults to restrict their oral fluid intake. Furthermore, those from lower socioeconomic backgrounds, living alone, with pre-existing comorbidities, or on multiple drugs are more susceptible to dehydration and electrolyte disturbances, and are at increased risk of associated morbidity and mortality.[5] Poor patient education has also been reported to lead to high rates of dehydration-related hospital readmissions after discharge, particularly in surgical patients.[6–8] Dehydration has been shown to be the main reason for readmission following formation of a defunctioning ileostomy, with those on diuretics being at increased risk.[8] Higher mortality rates at one year have been noted in those readmitted to hospital after surgery for hip fracture, a significant proportion of which were related to dehydration.[7]

Age-related physiological changes, including renal senescence also increase the susceptibility of the older adult population to

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dehydration. Dehydration of as little as 2% of total body water can result in a significant impairment in physical, visuomotor, psychomotor and cognitive performances.[9] Furthermore, a study reported a 17%, 30-day mortality in older adults with the principal diagnosis of dehydration as per the ICD classification, with the one-year mortality being close to 50%.[10]

Older adults are also susceptible to water retention and related electrolyte abnormalities. These are exacerbated at times of physiological stress, such as in the perioperative period[11] and a positive fluid balance has been shown to be an independent risk factor for mortality in critically ill patients with acute kidney injury.[12,13]

The aim of this narrative review of the current literature is to highlight the key aspects of age-related pathophysiological changes that affect fluid and electrolyte balance in older adults and underpin their importance in the perioperative period.

2. Search strategy

The Web of Science, MEDLINE, PubMed and Google Scholar databases were searched using the terms elderly, older adults, ageing, fluids, electrolytes, hydration, dehydration, hypohydration, dysnatraemia, sodium, hypernatraemia, hyponatraemia, magnesium, hypomagnesaemia, hypermagnesaemia, potassium, hyperkalaemia, hypokalaemia and thirst, using the Boolean operators AND/OR for relevant studies from the 15 years preceding June 2013. Randomised controlled trials and large cohort studies were sought; other studies were used when these were not available. The bibliographies of extracted papers were also searched for relevant articles. Older papers were included if the topic was not covered by more recent work. Papers published in languages other than English, small case series and case reports were excluded.

3. Physiological changes in older adults

The ageing process is associated with physiological changes in water balance. Total body water is reduced by 10–15% in older adults, owing to reduced lean body mass, leading to an increased extracellular to intracellular water ratio.[3] This, coupled with reduced glomerular filtration rate and a reduced ability to concentrate urine, can predispose older adults to fluid retention and iatrogenic overload.[3,14]

Physiological changes associated with ageing also make older adults more susceptible to organ dysfunction, including acute and chronic kidney injury, which can result in electrolyte abnormities. Electrolyte abnormalities can also occur without any obvious kidney disease as a result of structural and functional changes associated with ageing.[15,16]

Fluid intake is primarily through oral ingestion of fluid: this is stimulated by the thirst mechanism which may be impaired in older adults, as a consequence of hormonal changes.[17–19] The daily fluid turnover in older subjects was found to be at the lower limits of normal when assessed using deuterium oxide.[20] Furthermore, the daily water turnover was on average, 27% less in dependent older patients living in institutional care compared with those living in their own homes.[20]

Fluid loss occurs mostly through the urinary system, but variable amounts are attributed to insensible losses which can be up to 800 ml in 24 h, via the skin, gastrointestinal tract and lungs. Age-related skin changes make older adults vulnerable to extreme changes in environmental temperature. There is a decrease in the water content of the stratum corneum[21] and a significantly higher transepidermal water loss from most anatomical regions compared with younger patients.[22] Furthermore, decreased elasticity and skin turgor as well as the dry appearance of the aged skin make it harder to diagnose dehydration in older adults. The magnitude and distribution of fluid losses are influenced by the environment, disease and the physiological changes occurring with ageing.[23]

4. Renal senescence

Renal senescence reflects irreversible structural and functional changes associated with the ageing kidney.[16] Amongst other changes, there is a loss of renal mass due to glomerular sclerosis and glomerular loss.[14,24,25] This impairs the ability to retain sodium and, therefore, water, thus predisposing the patient to dysnatraemia and hypovolaemia.[26] In addition, the ability to secrete potassium and excrete hydrogen is also impaired.[27–29] The creatinine clearance in the aged kidney is also reduced. Reduction in the mean creatinine clearance was reported in two-thirds of the population studied in the Baltimore Longitudinal Study of Ageing, with an estimated reduction in eGFR by 50–63% from the age of 30–80 years.[14] Furthermore, reduced tubular function and the medullary concentration gradient are also impaired in an aged kidney, diminishing the ability of the kidney to concentrate urine. Age-related reduction in renal blood flow has also been reported; this contributes to loss of nephrons as a result of ischaemia.[14,30–32] These changes impair the ability of the kidney to control water and electrolyte balance, predisposing to dehydration and electrolyte abnormalities, particularly in situations of physiological stress.

5. Hormonal changes and ageing

Hormonal changes that affect fluid and electrolyte homeostasis have been reported in older adults. There is an age-related reduction in the serum concentrations of renin and aldosterone as a result of increased atrial natriuretic peptide (ANP) activity, usually released in response to increased blood pressure and right atrial filling.[33] This, coupled with age-related reduction in tubular response to aldosterone, predisposes to dehydration and electrolyte abnormalities.[32,34] Serum ANP concentrations were shown to

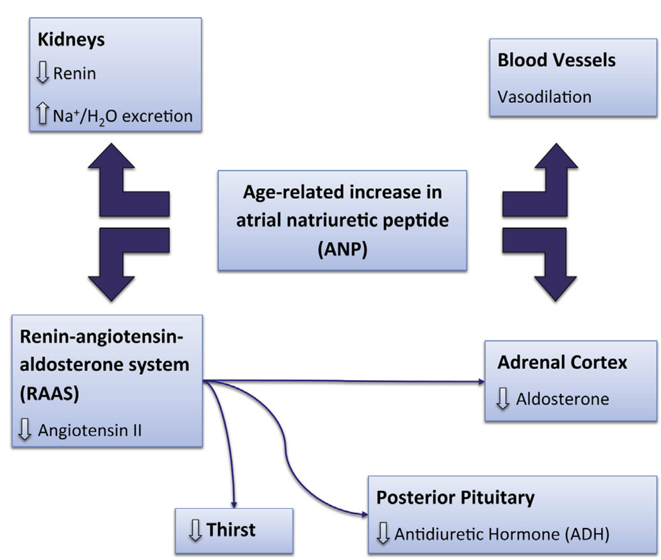

Fig. 1. Age-related changes in the hormonal control of fluid and electrolyte homeostasis. There is an age-related reduction in the serum concentrations of renin and aldosterone as a result of increased atrial natriuretic peptide (ANP) activity. ANP inhibits renin secretion from the juxtaglomerular cells, therefore, limiting the conversion of angiotensinogen to angiotensin I, ultimately resulting in reduced angiotensin II, therefore inhibiting the renin–angiotensin–aldosterone system (RAAS). Consequences of this include; reduced aldosterone, impaired thirst response, reduced antidiuretic hormone. These changes result in a decreased ability to retain sodium and water making it difficult to adapt to extracellular fluid depletion and sodium loss.

be nearly five-times higher in older adults than in the young.[35] ANP inhibits renin secretion from the juxtaglomerular cells, therefore, limiting the conversion of angiotensinogen to angiotensin I, and reducing the activity of the renin–angiotensin–aldosterone system (RAAS) (Fig. 1).[36] These changes result in a decreased ability to retain sodium in a hypovolaemic state and a reduced ability to excrete potassium,[27,37] making it difficult to adapt to extracellular fluid depletion and sodium loss.

It is also important to consider the role of antidiuretic hormone (ADH) in older adults, where there is conflicting evidence suggesting increased as well as decreased serum concentrations. ADH acts to stimulate aquaporin, a group of proteins that allow the passage of water across cell membranes and thus conserve the body water. The normal diurnal variation results in increased plasma concentrations of ADH at night, but in older adults there is loss of the nocturnal rise in ADH concentrations which contributes to the high prevalence of nocturia.[38] This, along with reduced renal sensitivity to ADH, limits the ability to respond to extracellular fluid depletion.[32,39,40] Furthermore, decreased plasma ADH concentrations have been reported in patients with Alzheimer's disease, limiting the ability to conserve water.[41]

6. Thirst response

The thirst response is blunted in older adults resulting in a persistent hyperosmolar state,[42–47] which is exacerbated by the reduced concentrating ability of the kidney. In a double-blinded crossover study investigating the thirst response in older men, healthy men aged 65–78 and 25–32 years were infused with isotonic, 0.154 M (0.9%) saline or hypertonic, 0.855 M (5% saline) two weeks apart.[43] The authors reported less volume expansion in older adult subjects following hypertonic saline than in the younger subjects. Moreover, older adults felt less thirsty and consumed less water than the younger subjects during the hypertonic state, thus demonstrating the increased thirst threshold in older adults.[43] Another study showed that older men had a blunted thirst response following 24 h without fluids when compared with younger men.[18] The mechanism responsible for this is yet to be defined, but may be a result of blunted osmotic and baroreceptor sensitivity, particularly in the left atrium[17,46] or possibly inhibition of the RAAS as a result of the raised concentrations of ANP.[48] It is important to note, however, that the amount of fluid consumed on a daily basis is not entirely physiologically driven, but is dependent on consumption that is driven by social factors, habit and other influences, such as the fluid intake with meals.[17,49] Therefore, the healthy independent older person is generally able to maintain adequate fluid balance through spontaneous consumption of fluids but may become vulnerable to dehydration in a state of physiological stress.

7. Electrolyte abnormalities in older adults

Electrolyte abnormalities, particularly dysnatraemia, should be considered in the context of water balance. Hypertonic dehydration occurs when proportionally more water than sodium is lost from the extracellular fluid compartment. This may occur as a result of age-related thirst impairment and would manifest as serum sodium concentration of greater than 145 mmol/l in the context of dehydration. Hypotonic dehydration on the other hand occurs when the proportion of sodium lost is greater than water, resulting in a serum sodium concentration of less than 135 mmol/l. This may occur with the use of diuretics. Isotonic dehydration results from proportionate loss of water and sodium and results in normal serum sodium concentrations. Isotonic dehydration may occur, for example, as a result of diarrhoea, where there is salt and water loss in similar proportions.

7.1. Dysnatraemia in older adults

The hyperosmolar state of the older person predisposes to dysnatraemia, the most common electrolyte abnormality in older adults, with age being an independent risk factor for dysnatraemia.[26] Clinical manifestations of dysnatraemia vary depending on the severity, with fatigue, seizure and coma being recognised complications. Dysnatraemia, particularly hypernatraemia, is also associated with an increased mortality rate of up to 70% in severe cases.[50,51] A seven fold increase in mortality was also reported in patients with hypernatraemia compared with age-matched hospitalised patients.[51] In an audit of 1383 surgical inpatients, it was found that patients with dysnatraemias had a significantly higher mortality than those with normal serum sodium concentrations (12.7 *vs.* 2.3%, $p < 0.001$).[52]

Hyponatraemia, on the other hand, is much more common in older adults than hypernatraemia and is an independent risk factor for bone fractures.[53–55] This, may be a result of reduced bone mineral density and increased risk of osteoporosis.[56] Moreover, hyponatraemia was associated with a 2.1-fold increase in mortality in mild cases and 4.6-fold increase in severe cases in patients admitted for orthopaedic surgery.[54,57]

It is important to note that a significant proportion of dysnatraemia in older adults occurs as a result of concurrent disease such as the syndrome of inappropriate ADH secretion (SIADH) and hyperglycaemia.[58] Iatrogenic causes of dysnatraemia, such as diuretic use as well as excessive administration of intravenous hypotonic fluids, must also be considered. Increased dietary salt content of processed foods on which many older adults are now dependent, and excess iatrogenic salt administration result in hypernatraemia as older adults require longer to excrete salt loads due to the age-related reduction in eGFR and they are more likely to become salt and water overloaded when challenged with a sodium load. The kidney is also unable to cope with the excess chloride load even in physiologically normal younger subjects.[59]

7.2. Other electrolyte abnormalities in older adults

Age-related renal changes make older adults vulnerable to other electrolyte abnormalities, in particular hyperkalaemia, resulting from impaired ability to secrete potassium and excrete acid, a consequence of age-related decline in distal renal tubular function.[27–29,60] This is further exacerbated by a blunted renin and aldosterone response. It has been shown that there was a reduced aldosterone response to potassium infusion in healthy older adult volunteers when compared with younger controls.[61] Furthermore, the age-related blunting of the renin-aldosterone response to an acute rise in serum potassium further increases the susceptibility to hyperkalaemia.[62] Other mechanisms have also been suggested to contribute to hyperkalaemia. Transtubular potassium concentration gradient, an index of potassium secretory activity in the distal tubule, was shown to be lower in healthy older adult subjects than in the young.[27] This highlights the need to monitor for hyperkalaemia in older adults when prescribing medication, particularly in those who are physiologically stressed.

Hypomagnesaemia has also been reported to be associated with normal ageing, often as a result of low dietary intake, but it is also known to be linked to acid-base status, with renal magnesium loss exacerbated by an acid load.[63–65] Hypomagnesaemia is associated with a variety of heterogeneous disease processes and is known to reduce renal calcium reabsorption. If untreated, it can cause osteoporosis, arrhythmias and myocardial infarction. Slow progress, morbidity and even mortality have also been reported in the intensive care setting in association with hypomagnesaemia.[64,66]

8. Prescribing in older adults

The predisposition of older adults to electrolyte abnormalities is further increased by the underlying co-morbidities that often coexist and can often be precipitated by polypharmacy. Some drugs also interfere with thermoregulation and predispose to dehydration (Table 1).[67] Medications such as angiotensin-converting enzyme inhibitors (ACE-I), potassium-sparing diuretics and non-steroidal anti-inflammatory drugs (NSAIDs) also interfere with potassium homeostasis. ACE-I prevent the conversion of angiotensin I to angiotensin II, thereby reduce aldosterone secretion. NSAIDs inhibit prostaglandin synthesis, associated with reduced renin and aldosterone, thus predisposing to hyperkalaemia.[60,68]

NSAID prescribing in older adults is limited due to significant gastrointestinal side effects. However, older adult patients are susceptible to dehydration and significant electrolyte abnormalities with widespread unmonitored diuretic prescriptions.

Complications associated with diuretic use are reported widely.[69–71] Various studies have concluded that adverse events related to diuretics are amongst the most commonly reported.[72,73] A study showed that 25% of the adverse drug reactions reported in an older adult population were related to diuretic therapy, and all those admitted to hospital with medication-related falls were on diuretics.[72] Various theories have been suggested for this. A systematic review into adverse drug reactions in ambulatory care that lack of monitoring of diuretic use caused over- or under-diuresis and potentially preventable hospitalisation.[74] The lack of patient education on the effective use of diuretics may also play a role in this, with a clear role for patient-led regulation of personal diuretic use based on regular weight measurement, empowering them with sufficient knowledge to decide on the daily doses.[3] Furthermore, sufficient information needs to be conveyed to allow the patients to recognise dehydration and to omit diuretics when they are at increased risk of fluid and electrolyte loss.[3] The use of diuretics should be monitored closely, particularly in older adults who are at increased risk or dehydration and potentially significant electrolyte abnormalities in the same way that glycaemic control is monitored.[74]

9. Dehydration and the environment

During ill health or periods of hot weather older adults are at particular risk of dehydration.[75,76] A heat wave in France in 2003 was associated with a 160–200% increase in mortality, mostly associated with dehydration and electrolyte abnormalities,[76] owing to the diminished ability of older adults to thermoregulate as a result of reduced total intra and extracellular fluid. This results in reduced sweat production and is exacerbated by dehydrated and dry skin which reduces heat loss and acts to insulate.[10] This reduction in total body water worsens the severity of dehydration which is more dependent on the relative loss of total body water rather than the absolute loss.[10,77]

Table 1
Commonly prescribed drugs that affect thermoregulation and increase body temperature.

- Levothyroxine
- Selective serotonin reuptake inhibitors (SSRI)
- Atypical antipsychotics e.g. olanzapine
- Tricyclic antidepressants
- Carbamazepine
- Anticholinergics
- Antihistamines

10. Dehydration and cognitive impairment

Cognitive impairment is a risk factor for dehydration, particularly in older adults.[78] However, there are few clinical studies that investigate dehydration in the cognitively impaired despite this increased risk. People with dementia often forget to drink, increasing the risk of dehydration, which may lead to further cognitive decline and further dehydration. Dehydration of as little as 2% may cause impaired cognitive function.[9,79] Most agree, however, that further work is needed in this field to further clarify the extent of cognitive impairment in dehydrated older adult patients.

11. Diagnosing dehydration

Electrolyte abnormalities and dehydration, although common in older adults, are relatively simple to treat. However, recognising dehydration can be difficult in nursing home subjects and hospital patients partly due to poor monitoring and the challenges in recording accurate fluid balance that accounts for actual input and output as well as insensible fluid loss which is influenced by the disease process.[80] The limited knowledge of frontline staff surrounding hydration is also a contributing factor.[81] This, coupled with the difficulty in recognising the symptoms and signs of dehydration in older adult patients, can result in morbidity and even mortality.

Clinical manifestations of dehydration include dry skin, reduced skin turgor and dry mucous membranes (Table 2). However, reduced skin turgor can occur with age and the commonest cause of dry mouth in older adults is mouth breathing. Other features of dehydration include dizziness weakness and apathy, all of which my erroneously be attributed to other causes or simply ascribed to the ageing process making dehydration difficult to diagnose.[75,82] A prospective observational study was performed to identify accurate indicators of dehydration in older adults.[82] The authors reported various symptoms and signs as markers of dehydration, including dry axilla which was shown to have a sensitivity of 44% and a specificity of 89% in those with a urinary osmolality greater than 295 mOsm/L, but concluded that clinical assessment coupled with appropriate laboratory investigations were key to diagnosing dehydration in older adults accurately.[82]

Table 2
Clinical and biochemical features of dehydration.

Clinical features
- Dry mucus membrane
- Dry skin
- Reduced skin turgor
- Reduced axillary sweating
- Orthostatic hypotension
- Tachycardia and hypotension (indicates shock)
- Cognitive impairment
- Reduced urinary output [<0.5 ml/kg/h is suggestive of acute kidney injury (AKI)]
- Concentrated urine and high osmolality

Biochemical changes
- Raised serum urea
- Raised creatinine (>26 μmol/L within 48 h or $>1.5\times$ upper limit within one week indicate AKI)
- Reduced estimated glomerular filtration rate (eGFR)
- Increased urea:creatinine ratio (>80)
- Hypernatraemia (loss of water greater than salt loss)
- Raised serum or urine osmolality
- Raised urine specific gravity

12. Physiological changes during the perioperative period

The older adult population makes up a significant proportion of the surgical population. This is largely due to advances in medical care allowing the provision of more effective and less traumatic surgery. In combination with significant improvement in preoperative optimisation and more intensive postoperative monitoring and treatment, this has led to improved outcomes in the older adult surgical patient. Surgery, however, is associated with a stress response similar to that following trauma and results in a systemic response mediated by neurological, hormonal, immunological and haematological responses.[11] This multisystem response to surgery, although essential to recovery, can be associated with poor outcome if not managed effectively, particularly given the physiological changes that occur with age. Amongst the physiological changes that occur during the acute phase of the stress response to surgery is an increased secretion of ADH from the posterior pituitary, resulting in increased water retention. Increased sympathetic efferent activity results in increased renin secretion and therefore increased aldosterone resulting in further water and sodium absorption. These changes make the older adult more vulnerable to salt and water retention.[11] Although designed to maintain adequate cardiac output and renal perfusion, salt and water retention can be associated with delayed postoperative recovery and poor outcome.[83] Perioperative fluid therapy has a direct bearing on outcome.[84] Morbidity caused by salt and water retention includes cardiorespiratory complications, increased infection risk and impaired wound healing.[85] Impaired gastrointestinal function has also been reported in association with postoperative salt and water retention.[84,86–88] A randomised controlled trial investigating the effects of salt and water balance on recovery of gastrointestinal function after elective colonic resection, reported that positive salt and water balance delays return of gastrointestinal function and prolongs hospital stay.[87] This delayed recovery could result from mesenteric oedema that compromises blood flow to the bowel.[89,90] The same mechanisms contribute to prolonged postoperative ileus and intestinal failure and may inhibit anastomotic healing following bowel surgery.[88,90,91] Other studies have shown better outcome if intraoperative and postoperative fluids were restricted to maintain constant body mass and zero fluid balance.[92–95] The Sepsis Occurrence in Acutely Ill Patients study conducted across 24 European countries showed that a positive fluid balance was an independent risk factor for 60-day mortality in critically ill patients.[13]

13. Perioperative fluid management in older adults

Fluid and electrolyte therapy form an essential part of perioperative care and have a direct bearing on outcome.[84,91] The UK national confidential enquiry into perioperative deaths in 1999 found that at the extremes of age errors in fluid management, usually fluid excess, were the most common cause of avoidable postoperative morbidity and mortality, further highlighting the importance of accurate fluid prescription in older adults.[96]

The perioperative fluid regimen is dependent on the quantity of fluid prescription as well as amount of electrolytes administered. 0.9% sodium chloride (saline) is one the most commonly used intravenous crystalloids in the world.[97] It is commonly prescribed in surgical patients and has been shown to cause hyperchloraemic acidosis in large volumes, even in healthy subjects.[33,98,99] Human studies have also shown sodium balance remains abnormal for up to two days post infusion of normal saline with associated suppression of the RAAS.[100] Moreover, studies have reported higher complication rates and the need for renal replacement therapy in patients who had received 0.9% saline than in those who received balanced crystalloid solutions following major open abdominal surgery (Fig. 2).[101] Furthermore, chloride-restrictive intravenous fluid therapy has been shown to reduce the incidence of acute kidney injury and the need for renal replacement therapy in ICU patients.[102] A randomised controlled double-blinded crossover study where two litres of saline or Plasma-Lyte (a balanced solution) were administered intravenously to healthy volunteers reported for the first time in humans that saline resulted in reduced renal blood flow velocity and cortical tissue perfusion.[59] This is likely to further increase salt and water retention, with older adults at increased risk because of the age-related physiological changes and the high incidence of renal failure and heart failure in this group. Saline-induced hyperchloraemic acidosis was also suggested to prolong postoperative recovery through reduced gastric blood flow and intramucosal pH in older adult patients.[90,95] In contrast,

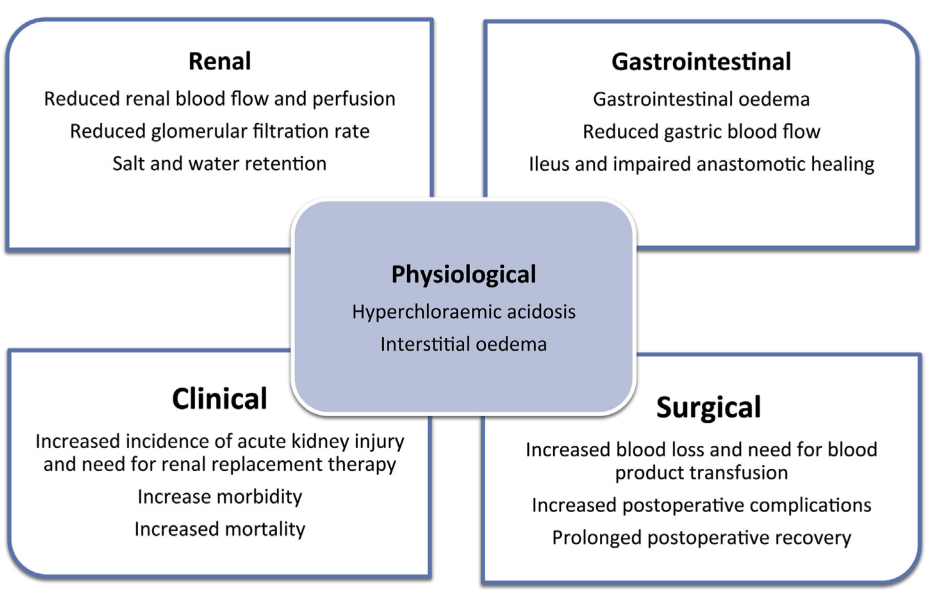

Fig. 2. Complications that are increased with 0.9% saline relative to balanced crystalloids.

balanced crystalloids induce less of a sodium and chloride load compared with saline and do not induce hyperchloraemic acidosis, leading to more rapid sodium excretion.[98,99] A very recent study demonstrated a 22% incidence of acute postoperative hyperchloremia (serum chloride >110 mmol/l).[103] Patients with hyperchloremia were at increased risk of 30-day postoperative mortality [3.0% *vs.* 1.9%; odds ratio (95% CI): 1.58 (1.25–1.98)] and had a longer median hospital stay [7.0 days (IQR 4.1–12.3) *vs.* 6.3 days (IQR 4.0–11.3), $p < 0.01$] than those with normal postoperative serum chloride concentrations.[103] Patients with postoperative hyperchloremia were also more likely to have postoperative renal dysfunction as defined by $a > 25\%$ decrease in GFR (12.9% *vs.* 9.2%, $p < 0.01$).

Monitoring of fluid input and output in all surgical patients is of great importance as a knowledge of fluid balance can help direct adequate fluid replacement where needed. This is usually poorly recorded on fluid balance charts and there are difficulties in accurately accounting for insensible fluid losses because these vary depending on the environment and on the disease process. Monitoring of perioperative fluid balance after liver transplant with controlled, appropriate negative fluid balance in the first three perioperative days has been shown to decrease the incidence of postoperative pulmonary oedema and lead to better postoperative recovery.[104,105] Furthermore, a meta-analysis of randomised clinical trials of intravenous fluid therapy in major elective open abdominal surgery reported a reduction in postoperative complications by 41% and length of hospital stay by 3.4 days in patients managed with appropriate (near zero) fluid balance as opposed to states of fluid imbalance.[95] Moreover, various studies have shown that in high risk patients flow guided intraoperative fluid therapy and provision of small (200–250 ml) boluses of colloid to optimise stroke volume, results in a significant improvement in outcome.[106–114] However, such invasive means of monitoring patients may not be of additional benefit where patients receive accurate postoperative fluid management.[115,116]

14. Fluid prescribing in the older adult surgical patient

Salt and water retention is of great importance, but fluid prescription is often left to the most junior members of the medical team. Numerous studies have shown that inaccurate prescription of fluid results in fluid overload: some patients were reported to receive up to 5 L of excess water and 500 mmol of excess sodium (and chloride) per day.[117,118] If perioperative optimisation of fluid and electrolyte balance is to be achieved, doctors need to be well informed and, therefore, empowered to make accurate decisions on fluid prescription. This was shown to be achievable through the provision of a dedicated fluid and electrolyte physiology interactive workshop and maybe useful in tackling current gaps in knowledge and training.[119]

15. Conclusion

The ageing population has increased in recent years due to advances in medical care. Work published in the 21st century has highlighted significant morbidity and mortality related to fluid and electrolytes abnormalities in older adults. Despite this, there is still major need for improvements in the way these key issues are assessed and managed. Age-related pathophysiological changes coupled with polypharmacy and poor physiological reserves predispose older adults to significant fluid and electrolyte abnormalities, particularly in the face of physiological stress. Improved awareness and monitoring together with better patient education is key. This together with knowledge of age-related pathophysiological changes, including renal senescence and age-related hormonal changes which directly effect fluid and electrolyte balance in older adult surgical patients are essential to diagnose and manage this common, yet potentially fatal, problem.

Author contributions

AMEl-S: Study design, literature search, selection of studies, data interpretation, writing of the manuscript and final approval.

OS: Study design, data interpretation, critical revision of the manuscript and final approval.

RM: Study design, data interpretation, critical revision of the manuscript and final approval.

DNL: Study design, literature search, selection of studies, data interpretation, writing of the manuscript, critical revision and final approval.

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Conflict of interest

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