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Patterns and Clinical Outcomes Associated with Routine Intravenous Sodium and Fluid Administration after Colorectal Resection

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Abstract. Excess intravenous water and sodium may be associated with postoperative complications and an adverse outcome. However, the effect of the magnitude of the surgery on such a relation has not been studied. This study assesses current practice in intravenous fluid and sodium administration after colonic and rectal resection and its relation to the postoperative outcome. A series of 100 consecutive patients undergoing elective colonic ($n = 44$) or rectal resection ($n = 56$) were included in a retrospective case-cohort study. The volumes of water and sodium from intravenous fluid and antibiotic administration on the day of surgery and the next 5 days were recorded together with the clinical outcome. The mean ± SEM fluid and sodium administration on the day of operation was greater after rectal than colonic resection (4.6 ± 0.2 vs. 3.6 ± 0.2 liters and 507 ± 34 vs. 389 ± 22 mmol, respectively ($p < 0.05$). The mean ± SEM rate of daily fluid and sodium administration for the 5 subsequent days was greater following rectal than colonic resection (2.1 ± 0.1 vs. 1.8 ± 0.1 L/day and 155 ± 8.7 vs. 128 ± 8.0 mmol/day; $p < 0.05$). For all resections, there were no differences in fluid and sodium administration on the day of surgery in patients with or without postoperative complications. During the subsequent 5 days, patients with complications after colonic resection had a higher postoperative mean rate of intravenous sodium administration than those who did not (149 ± 12 vs. 115 ± 10 mmol; $p < 0.05$). A similar pattern was not observed following rectal resection. Current postoperative intravenous fluid prescription delivers approximately 2 liters of fluid and 140 mmol of sodium per day. Complications after colonic, but not rectal, resection are associated with more early postoperative daily intravenous sodium administration. Because colonic resection poses less of a physiologic insult than rectal resection, the overall outcome in the former group may be more sensitive to the interplay between fluid and sodium overload and patient co-morbidity.

Intravenous fluid and electrolytes are given to resuscitate the patient from losses sustained during surgery and to maintain homeostasis during periods when oral intake may not be possible. Clearly, the more major the surgery, the greater is the intravenous fluid requirement. However, the optimum fluid replacement strategy during and following surgery remains controversial. Many centers do not have a protocol for intraoperative fluid administration and continue to advocate the delivery of 3 liters of fluid and 154 mmol of sodium per day to postoperative patients [1]. However, such fluid prescription regimens are reported to be associated with a positive fluid balance in excess of 3 liters by the fourth postoperative day [2]. This excess input of sodium and water may be associated with increased postoperative complications and an adverse outcome [3, 4]. Nonetheless, the precise nature of the current fluid and sodium prescription practice is unclear, as is the interaction between the magnitude of surgery, perioperative fluid prescription, and the development of postoperative complications.

This study documents the current practice regarding the duration and volume of postoperative fluid and electrolyte administration in patients undergoing elective colonic or rectal resection. It also aims to compare the effects on the outcome of such intravenous fluid and sodium administration in patients undergoing modest colonic surgery versus major rectal surgery.

Materials and Methods

Patients

A series of 100 consecutive patients undergoing elective colorectal resection with primary anastomosis over a 10-month period (October 2000 to July 2001) on one colorectal service were included in the study. Patients undergoing complex pelvic reconstruction or resection without colonic anastomosis were excluded. Patients were classified as having undergone segmental colonic or rectal resection (Table 1). Total colectomy was classified as a rectal procedure to reflect the extent of surgery involved and the need for rectal dissection.

Preoperative bowel preparation comprised two sachets of Picolax on the day prior to surgery with unlimited clear oral fluids up to midnight. Thereafter patients were kept fasting. A single dose of a parenteral prophylactic antibiotic was administered on induction

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Table 1. Nature of the operation performed in 100 patients undergoing colorectal resection.

Operation	No. of patients
Segmental colonic cohort	
Right hemicolectomy	32
Left hemicolectomy	8
Transverse colectomy	3
Rectal cohort	
Anterior resection	45
Colectomy with ileorectal anastomosis	7
Resection rectopexy	4

of anesthesia. No set guidelines for postoperative intravenous fluid management were imposed, and all patients were treated in accordance with the established practice of the attending anesthetist and one of three colorectal surgeons.

Study Design

This study was approved by the Lothian Research Ethics Committee. Patients' case notes were reviewed retrospectively. Demographic information was gathered together with preoperative anthropometric results, American Society of Anesthesiologists (ASA) grade, the Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity (POSSUM) score, and the operative indication [5].

Operative factors including the nature of the surgery, the duration of the surgery, and the intraoperative blood loss were identified. The quantity of intravenous fluid (including blood and blood products) and sodium replacement including antibiotic administration (which may contain a significant quantity of sodium) from midnight of the day of operation (day 0) to the fifth postoperative day (day 5) was recorded. The rate of postoperative intravenous fluid and sodium prescription was the mean of each individual's daily intravenous fluid and sodium on the days they received intravenous fluids from day 1 to day 5.

Outcome measures included the duration of high dependency unit (HDU) care, time to cessation of intravenous fluids, postoperative hospital stay, in-hospital morbidity as defined in Appendix 1 [6], 30-day readmission rate, and 30-day mortality.

Statistics

Statistical analysis was performed using SPSS for Windows Release 11.0.0 (SPSS, Chicago, IL, USA). Continuous variables were compared with student's *t*-test and the Mann-Whitney U-test. Categoric variables were compared using the χ^2 and Fisher's exact tests. Differences were considered significant at $p < 0.05$.

Results

The demographic profile, operative characteristics, and outcomes of patients are shown in Tables 2 and 3.

The greatest input of both fluid and sodium occurred on the day of operation. Patients undergoing segmental colonic resection received a mean ± SEM intravenous fluid and sodium load of 3.6 ± 0.2 liters and 389 ± 22 mmol, respectively. Patients undergoing rectal resection received significantly more intravenous fluid and sodium on the day of surgery than did those having segmental colonic resection: a mean ± SEM of 4.6 ± 0.2 liters of fluid ($p = 0.002$) and 507 ± 34 mmol of sodium ($p = 0.020$).

By day 5 the mean cumulative total intravenous fluid and sodium inputs of patients having segmental colonic resections were 10.4 ± 0.5 liters and 874 ± 54 mmol, respectively. Once again, patients undergoing rectal resection received significantly more cumulative total intravenous fluid and sodium than patients having segmental colonic resection: 13.2 ± 0.6 liters of fluid ($p < 0.001$) and 1168 ± 67 mmol of sodium ($p = 0.001$).

Patients undergoing segmental colonic resections received a mean ± SEM daily rate of intravenous input of 1.8 ± 0.1 liters of fluid and 128 ± 8 mmol of sodium per day. This was significantly less than their counterparts undergoing rectal resection, who received 2.1 ± 0.1 liters of fluid ($p = 0.031$) and 155 ± 9 mmol of sodium ($p = 0.031$) per day.

The number and type of postoperative complications are shown in Table 4. The overall (segmental colonic and rectal cases combined) observed complication rate was 36%; the anastomotic leak rate was 5% and the 30-day mortality 1%.

Outcome after Segmental Colonic Resection

Of the 44 patients undergoing segmental colonic resection, 17 (39%) developed a postoperative complication (Table 2). Those who developed postoperative complications had lengthier operations ($p = 0.038$) and were more likely to have required preoperative epidural analgesia ($p = 0.008$). There were no differences in the ASA grade or the POSSUM physiology or operative scores between patients who had had preoperative epidural analgesia and those who did not. There was one (2%) anastomotic leak and no 30-day mortality.

There was no statistically significant difference in mean intravenous fluid ($p = 0.310$) or sodium ($p = 0.101$) load on the day of surgery between patients who developed complications and those who did not. Patients who developed complications received a significantly greater mean ± SEM daily rate of intravenous sodium prescription: 149 ± 12 vs. 115 ± 10 mmol per day ($p = 0.034$) (Fig. 1a). However, this was not significant for the mean ± SEM daily rate of fluid input: 2.0 ± 0.1 vs. 1.7 ± 0.1 liters per day ($p = 0.120$) (Fig. 1b). The mean ±SEM cumulative intravenous fluid and sodium inputs over the first five perioperative days were 12.3 ± 0.8 liters and 1083 ± 91 mmol, respectively, for those with complications in contrast to 9.1 ± 0.5 liters of fluid ($p = 0.001$) and 742 ± 53 mmol of sodium ($p = 0.001$) in those without adverse outcomes.

Outcome of Rectal Resection

Of the 56 patients undergoing rectal resection, 19 (34%) developed a postoperative complication (Table 3). There were four (7%) anastomotic leaks and one (2%) death at 30 days.

There was no statistically significant difference in mean intravenous fluid ($p = 0.459$) or sodium ($p = 0.595$) load on the day of surgery between patients who developed complications and those who did not. There was no statistically significant difference in the mean ± SEM daily rate of intravenous fluid [2.2 ± 0.1 vs. 2.0 ± 0.1 liters per day ($p = 0.142$)] and sodium [172 ± 20 vs. 146 ± 8 mmol per day ($p = 0.166$)] prescription for patients with complications

Table 2. Demographics, operative factors, and outcome of patients undergoing segmental colonic resection.

Parameter	No complications (n = 27)	Complications (n = 17)	All resections (n = 44)
Age (years)	71 (22–91)	70 (31–92)	71 (22–92)
Sex (M:F)	14:13	6:11	20:24
BMI (kg/m^2)	22 (17–32)	27 (21–45)*	24 (17–45)
Disease			
Benign	9 (33%)	3 (18%)	12 (27%)
Malignant	18 (67%)	14 (82%)	32 (73%)
ASA score			
I	7 (26%)	1 (6%)	8 (18%)
II	14 (52%)	7 (41%)	21 (48%)
III	6 (22%)	9 (53%)	15 (34%)
IV	—	—	—
POSSUM			
Physiology score	19 (12–35)	16 (13–36)	18 (12–36)
Operative score	11 (8–17)	11 (7–17)	11 (7–17)
Epidural analgesia	0	4 (24%)*	4 (9%)
Operating time (minutes)	120 (60–270)	135 (75–240)*	120 (60–270)
Blood loss (ml)	< 100 (< 100 to 1170)	< 100 (< 100 to 1500)	<100 (< 100 to 1500)
Time in HDU (days)	0 (0–2)	1 (0–4)*	0 (0–4)
Postoperative stay (days)	8 (4–38)	11 (6–23)*	8 (4–38)
Time to cessation of IV fluids (days)	3 (2–6)	5 (2–17)*	4 (2–17)
30-day readmission	0	1	1 (2%)

Values are either medians and ranges or the number (with the percent).

ASA: American Society of Anesthesiologists; BMI: body mass index; POSSUM: physiological and operative severity score for the enumeration of mortality and morbidity; HDU: high dependence unit; IV: intravenous.

*$p < 0.05$, Mann-Whitney U-test: patients with no complications versus patients with complications.

Table 3. Demographics, operative factors, and outcome of patients undergoing rectal resection.

Parameter	No complications (n = 37)	Complications (n = 19)	All resections (n = 56)
Age (years)	70 (31–85)	69 (36–86)	70 (31–86)
Sex (M:F)	16:21	8:11	24:32
BMI (kg/m^2)	26 (19–35)	24 (14–35)	25 (14–35)
Disease			
Benign	10 (27%)	9 (47%)	19
Malignant	27 (73%)	10 (53%)	37
ASA score			
I	15 (41%)	4 (21%)	19 (34%)
II	15 (41%)	10 (53%)	25 (45%)
III	7 (19%)	4 (21%)	11 (19%)
IV		1 (5%)	1 (2%)
POSSUM			
Physiology score	17 (12–40)	20 (12–29)	17.5 (12–40)
Operative score	11 (8–18)	11 (10–24)	11 (8–24)
Epidural analgesia	6 (16%)	6 (32%)	12 (21%)
Operating time (minutes)	150 (80–270)	170 (70–270)	158 (70–270)
Blood loss (ml)	200 (< 100 to 4000)	495 (< 100 to 2200)	210 (< 100 to 4000)
Time in HDU (days)	1 (0–4)	1 (1–7)*	1 (0–7)
Postoperative stay (days)	9 (5–20)	13 (4–98)*	10 (4–98)
Time to cessation of IV fluids (days)	4 (2–10)	5 (2–27)	5 (2–27)
30-day readmission	0	1	1 (2%)

Values are either medians and ranges or the number (with the percent).

*$p < 0.05$, Mann-Whitney U-test: patients with no complications versus patients with complications.

and their counterparts without them (Fig. 1). There was no statistically significant difference in the mean ± SEM cumulative fluid and sodium inputs at day 5 [14.2 ± 1.1 vs. 12.7 ± 0.7 liters (p = 0.205) and 1275.0 ± 142.9 vs. 1113.0 ± 70.3 mmol (p = 0.257)] in patients who developed complications and those who did not.

Discussion

The work of Shires and colleagues in 1961 postulated a decrease in extracellular volume after surgery and recommended replacement of losses by additional fluid infusion. Since then, it has become routine practice for patients to be given large amounts of intravenous fluid after elective surgical procedures [7, 8]. The United Kingdom National Confidential Enquiry into Perioperative Deaths in 1999 recognized that errors in fluid and electrolyte management represented a significant cause of death [9]. However, there have been few contemporary studies documenting any practice in postoperative intravenous fluid replacement. The current data comprise an uncontrolled, retrospective review of a single center's practice.

Table 4. Postoperative complications.

Complication	Segmental resection (n = 17)	Rectal resection (n = 19)	All resections (n = 36)
Cardiorespiratory	3	8	11
Myocardial infarction	—	2	2
Pulmonary edema	—	1	1
Arrhythmia	1	2	3
Deep venous thrombosis	1	—	1
Pulmonary embolus	1	—	1
Renal failure	—	2	2
Other: angina	—	1	1
Surgical	3	8	11
Ileus	2	3	5
Anastomotic leak	1	4	5
Wound dehiscence	—	1	1
Infective	11	11	22
Respiratory tract infection	5	4	9
Urinary tract infection	3	2	5
Abdominal abscess	1	1	2
Wound infection	2	2	4
Sepsis	—	2	2

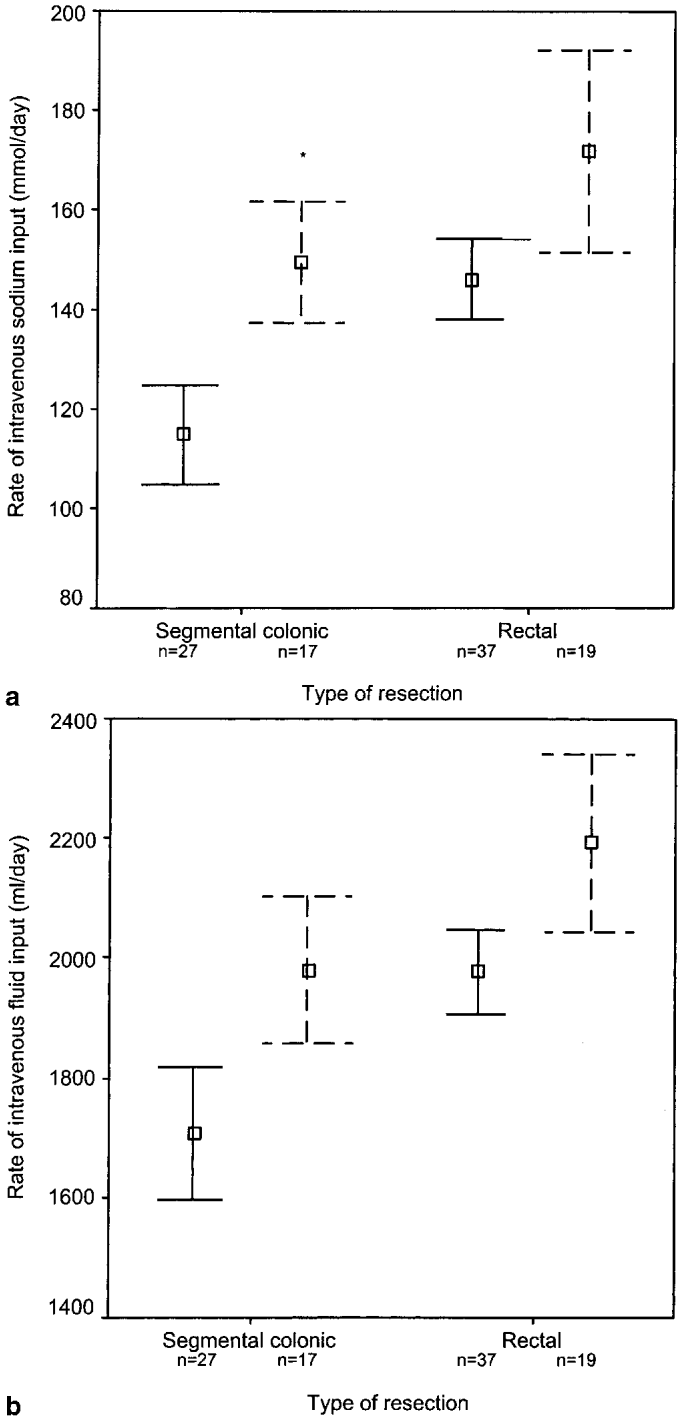

Fig. 1. a. Rate of daily intravenous sodium administration after segmental colonic resection or rectal resection. Values are the means ± SEM. *$p <$ 0.05 (unpaired student's t-test). **b.** Rate of daily intravenous fluid administration after segmental colonic resection or rectal resection. Values are means ± SEM. Box with solid line = no complication; box with dotted line = complication.

Fluid and electrolyte homeostasis in the postoperative patient is compromised by a reduced capacity to excrete excess sodium and water [2, 10, 11]. A common regimen for postoperative intravenous fluid prescription consists of 2 liters of 5% dextrose and 1 liter of 0.9% saline per day, which delivers 3 liters of water and 154 mmol of sodium. It has been suggested that such a policy may culminate in a significant positive fluid balance; and this excess administration of fluid may be associated with an adverse outcome and prolonged hospital stay [2–4].

The present data have shown that on the day of surgery the amount of fluid and sodium administration is greatly in excess of that of the regimen that comprises 2 liters of 5% dextrose and 1 liter of 0.9% saline daily. Patients undergoing both segmental colonic and rectal resection received approximately 35% of the 5-day cumulative total of intravenous fluid and 45% of the 5-day cumulative total of intravenous sodium on the day of surgery. Thereafter the patients received about 2 liters of fluid per day and 140 mmol of sodium: roughly 1 liter less of fluid but a similar load of sodium compared to the regimen of 2 liters of 5% dextrose and 1 liter of 0.9% saline. This proportionately more sodium than fluid in a number of patients is likely to stem from the use of sodium-rich colloid, crystalloid, and antibiotic solutions.

The benefits of restricting fluid to 2 liters per day and sodium to 77 mmol per day have been previously reported [2]. Brandstrup and colleagues' randomized, controlled trial of perioperative fluid restriction after elective colorectal resection demonstrated fewer postoperative complications in the study arm; it was also noted that sodium input was reduced in that cohort [12]. Based on the current data it appears that it is the salt content as well as the fluid volume that requires reduction.Patients undergoing segmental colonic resection who went on to develop complications received a significantly greater cumulative total of intravenous fluid and sodium than those without complications. Such a clear difference was not identified in patients undergoing rectal resection. However, there was a stepwise trend for patients with or without complications across the two operative cohorts. Equally, it is possible that the magnitude of the surgery, in part, determines the effect of a relative fluid and sodium overload and outcome. Because colonic resection poses less of a physiological insult than rectal resection, the overall outcome in such patients may be more sensitive to the interplay between fluid and sodium input and the patient's co-morbidity.

It could be argued that patients who developed complications required prolonged intravenous prescription. Therefore a larger cumulative sodium and fluid load would be an effect, rather than a cause, of postoperative complications. Indeed patients who developed complications after segmental colonic resection had more prolonged intravenous fluid administration, and a larger proportion of patients remained on intravenous fluid therapy up to day 5 than did patients without complications (59% vs. 15%; $p = 0.006$). However, analysis of the mean ± SEM daily input of the intravenous prescription on the first and second postoperative days after segmental colonic resection (when all patients remained on intravenous fluids) showed that those who developed complications had received a significantly higher rate of sodium administration on both the first (253 ± 37 vs. 170 ± 16 mmol/day; $p = 0.024$) and second (191 ± 21 vs. 143 ± 13 mmol/day; $p = 0.042$) postoperative days. Similarly, the daily mean ± SEM rate of intravenous fluid prescription was significantly higher on the second postoperative day for patients who developed complications than in those who did not (2.5 ± 0.1 vs. 2.1 ± 0.1 L/day; $p = 0.027$). These early differences in sodium and fluid prescription favor a causative relation, particularly in terms of sodium administration.

As noted previously, Lobo and colleagues reported the results of a prospective, nonblinded, randomized, controlled trial in patients undergoing segmental colonic resection comparing restriction of sodium to 77 mmol and fluid to 2 liters per day versus a conventional (2 liters 5% dextrose/1 liter 0.9% saline) fluid replacement strategy [2]. They noted significantly earlier discontinuation of intravenous fluids (day 4 vs. day 6) and postoperative discharge from hospital (day 6 vs. day 9) in their intervention arm. The control limb of the latter study had an approximate mean cumulative input of 16 liters of fluid and 1200 mmol of sodium by the fourth postoperative day, whereas the intervention cohort received 7.5 liters of fluid and 600 mmol of sodium.

Based on the present data, patients undergoing segmental colonic resection received a mean cumulative input of 10 liters of fluid and 849 mmol of sodium by the fourth postoperative day. Thus in the current series the doses of intravenous fluid and sodium administered were between those seen in the control and intervention arms of the study reported by Lobo et al. Similarly, outcomes in the present study (intravenous fluids discontinued on day 4, postoperative discharge on day 8) were between those of the control and the intervention arms of the study by Lobo and coworkers. Such a trend across studies tends to support the concept of a genuine relation between postoperative intravenous fluid/sodium administration and outcome.

The mechanisms by which excess perioperative intravenous fluid and sodium may mediate deleterious effects remain uncertain. An association between fluid overload, tissue edema, and reduced tissue oxygenation has been reported and may result in cardiorespiratory complications and compromised tissue healing [13]. It has also been reported that infusion of large amounts of 0.9% saline is associated with hyperchloremic metabolic acidosis. Such a derangement of acid-base status may impair cardiac contractility and reduce visceral perfusion [14].

Conclusions

An association between excess early salt and fluid prescription and adverse outcome after segmental colonic resection is highlighted by the present data. Although such a relation is supported by previous series, the optimum postoperative fluid regimen remains unclear. The present series supports a more conservative approach to perioperative sodium prescription in patients undergoing segmental colonic resection. However, further randomized controlled studies are required to determine if the large fluid and sodium load on the day of surgery can be reduced to beneficial effect.

Résumé. Un excès d'apports hydriques et sodés peut être responsable de complications postopératoires et d'évolution fâcheuse. Cependant l'importance d'un tel effet n'a pas été encore étudiée. Cette étude évalue les pratiques actuelles en ce qui concerne l'administration hydro-sodée après chirurgie colorectale et son rapport avec l'évolution postopératoire. Cent patients consécutifs ayant eu une résection élective colique ($n = 44$) ou rectale ($n = 56$) ont été inclus dans cette étude de cohorte rétrospective. Les données concernant le volume des apports hydro-sodés dans la perfusion par voie intraveineuse et l'administration des antibiotiques ont été enregistrées avec l'évolution clinique le jour de l'acte chirurgical et pour les quatre jours postopératoires consécutifs suivant l'intervention. La quantité moyenne (ET) des apports liquidiens et en sodium administrée le jour de l'intervention était plus grande après résection rectale qu'après résection colique [respectivement, 4.6 (0.2) vs. 3.6 (0.2) litres et 507 (34) *vs*. 389 (22) mmols ($p < 0.05$)]. La vitesse de perfusion moyenne (ETS) de liquide par jour d'eau et de sodium pour les quatre jours suivants a été plus grande après résection rectale qu'après résection colique [respectivement, 2.1 (0.1) vs. 1.8 (0.1) litres/jour et 155 (8.7) vs. 128 (8.0) mmols/jours ($p < 0.05$)]. Pour toutes les résections, il n'y avait aucune différence en ce qui concerne la quantité de liquide et de sodium administrée le jour de l'intervention chirurgicale avec ou sans complications postopératoires. Par contre, pour les quatre jours après, les patients ayant des complications après résection colique ont eu plus besoin de sodium en intraveineux que ceux qui n'en ont pas eu [149 (12) vs. 115 (10) mmols ($p < 0.05$)]. Ce besoin ne s'est pas manifesté de la même manière après résection rectale. La prescription postopératoire doit comporter approximativement deux litres d'apport hydrique et 140 mmols de sodium par jour. Les complications après résection colique, mais pas après résection rectale, sont associées à plus de besoins en sodium au début. Puisque la résection colique est moins agressive que la résection rectale au plan physiologique, l'évolution globale du premier groupe pourrait être plus sensible à la surcharge des apports hydro-sodés et à la co-morbidité du patient.

Resumen. Un exceso en la administracıın de agua y sodio puede verse asociado con complicaciones y una evolucıın clínica final adversa. Sin embargo, el efecto de la magnitud de la cirugía sobre tal asociacıın no ha sido debidamente analizado. El presente estudio fue diseñado para evaluar la práctica actual de la administracıın de líquido y de sodio por vía intravenosa luego de reseccıın de colon y de recto y su relacıın con la evolucıın postoperatoria. Cien pacientes consecutivos sometidos a reseccıın de colon ($n = 44$) o del recto ($n = 56$) fueron incluidos en un estudio retrospectivos de casos-cohorte. El promedio de líquido y de sodio administrado en el día de la operacıın aparecıı mayor en los pacientes con cirugía rectal que en los de cirugía colınica [4.6 (0.2) vs. 3.6 (0.2) litros y 507 (34) vs. 389 (22) mmoles ($p < 0.005$)]. También lo fue la rata de administracıın durante los siguientes cuatro días [2.1 (0.1) vs.1.8 (0.1) litros/día y 155 (8.7) vs.128 (8.0) mmoles/día ($p < 0.05$)]. Considerando la totalidad de las resecciones, no se hallı diferencia en los volúmenes de sodio y de líquido administrados en el día de la cirugía entre los pacientes con o sin complicaciones postoperatorias. Pero en los siguientes cuatro días los pacientes con complicaciones luego de reseccıın colınica registraron una mayor rata de administracıın de sodio que aquellos libres de complicaciones [149 (12) vs. 115 (10) mmols ($p < 0.05$)]. No se observı un patrın similar en los pacientes sometidos a reseccıın rectal. La práctica corriente de prescripcıın postoperatoria intravenosa de líquidos provee aproximadamente dos litros de líquido y 140 mmoles de sodio por día. Las complicaciones luego de reaccıın rectal, pero no de reseccıın colınica, aparecen asociadas con una mayor y más precoz administracıın diaria de sodio por vía intravenosa. Puesto que la reseccıın colınica constituye un mayor trauma fisiolıgico que la reseccıın rectal, el resultado global en el

primer grupo puede ser más sensible a la interacciın entre la sobrecarga de líquido y de sodio y con la comorbilidad en el paciente que es sometido a cirugía.

Appendix: Definition of Complications [6]

Cardiorespiratory complications
Respiratory failure (mechanical ventilation > 24 hours)
Cardiac failure (treated by inotropic or vasoconstrictive medication)
Pulmonary edema (radiologic diagnosis)
Pleural fluid (radiologic diagnosis)
Acute myocardial infarction (electrocardiographic diagnosis)
Acute renal failure (need for hemofiltration)
Stroke with neurologic symptoms
Pulmonary embolism, distal ischemia (digital angiography and clinical diagnosis)
Deep venous thrombosis (phlebography)
Others
Surgical complications
Unexpected blood loss > 0.5 liter during operation
Bowel perforation
Wound dehiscence
Postoperative bleeding (blood loss requiring > 2 units transfusion with normal clotting profile)
Delayed oral intake (intravenous fluids > 1 week owing to postoperative ileus)
Anastomotic leakage
Others
Infective complications
Sepsis (pyrexia > 38°C and septic focus or positive blood culture)
Postoperative peritonitis (clinical diagnosis)
Abdominal abscess (ultrasonography, computed tomography, or operative diagnosis)
Necrotizing fasciitis
Wound infection
Pneumonia (radiologic diagnosis)
Chest infection (e.g., mediastinitis, empyema)
Urinary tract infection
Disseminated intravascular coagulopathy
Others

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Fluids given intravenously bypass all the defenses set up by the body to protect itself against excess of any constituent, against bacterial entry . . . they give the patient what the surgeon thinks his tissues need and what they are damned well going to get.
—William Heneage Ogilvie, 1887–1971

One of my ex-chiefs used to say: "If the kidneys are OK you can give them even Coca Cola intravenously—they'll compensate." Indeed, most surgeons are quite blasé concerning perioperative fluid management, relegating this task to the junior staff. Moreover, if asked for advice, they would mention a fluid regimen based on the locally prevailing dogma. Such "dogmas," however, need an urgent update.

Let us start with a simplified historical background. The history of intravenous fluid therapy in surgical patients probably started in 1831 when W.B. O'Shaughnessy of London found severe deficits of water, salt, and alkali in victims of cholera and suggested intravenous (IV) replacement. A year later Thomas Latta of Scotland reported the first IV fluid resuscitation in a cholera patient. "She had apparently reached the last moment of earthly existence," he wrote, "having inserted a tube into the basilic vein cautiously—anxiously, I watched the effects; ounce after ounce (of water and salt) was injected . . . when six pints had been injected she acutely become jocular" [1].

Matters remained static until the early twentieth century when Gibbon (1907) wrote: "There are a few operations, however, after which water cannot be given by the mouth . . . the [postoperative] thirst can be largely relieved by giving large quantities of salt solution by the rectum." In 1908 John Benjamin Murphy wrote: "At-

tention must be turned to elimination of the products of infection . . . by washing the blood by the administration of large quantities of fluid, rarely by the stomach or intravenously, occasionally subdermally, but most frequently per rectum" [1]. It is Rudolph Matas of Tulane University, however, who is considered the father of modern intravenous fluid management. He wrote (1921): "Every surgeon knows that in grave cases . . . the rectal drip is not absorbed . . . especially when the portal circulation is stagnant as in advanced peritonitis. . . . Hypodermoclysis also fails when the capillary circulation is failing from shock after the operation" [2]. Matas administered 4000 to 5000 ml of 5% dextrose to his patients during the perioperative phase, thereby starting the "sugar era." During the 1930s Frederick Coller of Boston defined daily "insensible losses" to be up to 1000 ml of water (almost no salt). His postoperative daily fluid protocol included up to 2500 ml dextrose/water to maintain urine flow and compensate for insensible losses; abnormal gastrointestinal losses were replaced with saline. Coller warned about edema formation in patients receiving too much salt and stated: "No isotonic saline solution or Ringer's solution should be given during the day of operation and during the subsequent first two postoperative days" [1].

Then, during the 1950s, Carl A. Moyer warned against the "sugar only" regimen: "While the period of postop inhibition of water diuresis is present, one should not attempt to force a rapid flow of urine with dextrose/water because of the danger of *water intoxication*" [1]. Owen Wangensteen's group reported (1952) on 17 cases of postoperative water intoxication and recommended that "it may be wiser to give small amount of salt (4.5 9 grams) on the day after surgery," thereby starting the "back to salt" era [1].

Later, G. Tom Shires brought us to where we now stand—flooding our patients with water and salt. In 1961 he measured the acute changes in extracellular fluids associated with major surgical procedures and demonstrated one-third reduction of extracellular volume during uncomplicated major surgery; he blamed such "progressive marked diminution in functional extracellular fluid" on "the operative trauma itself." During subsequent years Dr. Shires and colleagues educated us in more than 100 chapters and 57 textbooks (http://www.unr.edu/med/dept/Surgery/fshires.html) that generous perioperative salt and fluid administration is the proper way to prevent shock, reduce the metabolic response to trauma, and preserve end-organ function. Today, most of us still use this practice, of course with the help of our anesthetists. We thus deluge our patients with salt and water. Recently, however, a few lone, but strong, voices are drawing our attention to the harm we may be doing.

Lobo et al. [3] randomized patients undergoing elective colonic resection to receive "standard" (2 liters of water, 1 liter of saline) versus "restricted" (1.5 liters of water, 500 ml of saline) daily intravenous regimens. Patients in the "restricted group" (zero positive balance by postoperative day 4) passed flatus, moved their bowels, went home earlier, and had fewer complications than patients in the "standard" group (3 liters positive balance on postoperative day 4). In another prospective randomized trial by Brandstrup et al. [4], the authors randomized 172 patients undergoing elective colorectal resections to a "restricted" or "standard" *intraoperative* and *postoperative* intravenous fluid regimen. Patients in the "restricted" group experienced a significantly reduced rate of both medical (e.g., cardiorespiratory) and surgical tissue healing complications. No patients in the "restricted" group died, whereas there were four deaths in the "standard" group. Clearly, swollen, edematous cells are bad signs in any system. Edema contributes to respiratory failure and cardiac dysfunction. It prevents tissue healing, adversely affecting intestinal anastomoses and fascial wounds. It swells abdominal contents, producing intraabdominal hypertension.

Finally to be considered is the present study by Tambyraja et al., who again draw our attention to the importance of "correct" perioperative fluid management. Their study was retrospective and assessed separately rectal and colonic cases (which I find "artificial" and unnecessary) because it is only logical that patients undergoing a "larger" rectal operation would need more fluids. The authors do, however, point out the adverse consequences of giving too much salt.

Let us now stop and reflect on what we are doing. It seems that we are giving our patients excessive salt and fluids. In medicine, as with any aspect of life, too much of even good things may be harmful.

References

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