Urine Output and Fluid Therapy during Anaesthesia and Surgery

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Summary: To try to determine whether fluid therapy during surgery should be on a large or a small scale 23 patients and six control subjects were studied. The control subjects were fasted and transfused with 2 litres of Ringer-lactate solution in one hour, the volume of urine output being measured at intervals for four hours. The patients were transfused similarly under varying conditions of anaesthesia and surgery. The characteristic urine output during abdominal hysterectomy followed a low, irregular pattern, and this occurred whether or not substantial amounts of fluid were transfused. In two patients anaesthesia and minimal trauma were associated with oliguria. An established diuresis was altered by anaesthesia and inhibited by surgery. These results indicate that excess Ringer-lactate solution administered during surgery may not be excreted and that overtransfusion could easily occur.

Introduction

The literature relating to current concepts of fluid therapy during surgery was reviewed recently (Parks, 1966). This clearly showed that two schools of thought existed. The more conservative school considered that the sodium and water retention observed during and after surgery was due to a temporary deficiency in salt and water homeostasis, and advocated restriction of fluid, and particularly sodium in the intraoperative and immediate postoperative period. This concept was largely derived from the work of Coller and his colleagues and confirmed by Le Quesne and his associates (Coller *et al.*, 1944, 1945; Moyer, 1950; Le Quesne and Lewis, 1953; Dudley *et al.*, 1954).

More recently the concept has grown that postoperative salt and water retention was due to fluid shifts, resulting in the loss of large volumes of extracellular fluid which was unrelated to blood losses (Randall and Papper, 1958; Shires *et al.*, 1961, 1964; Crenshaw *et al.*, 1962; Shires and Jackson, 1962). This diminution in interstitial fluid volume accounted for the observed sodium retention and oliguria. In this situation the transfusion of relatively large quantities of water containing salts in similar proportions to that found in the extracellular space could be expected to benefit the patient (Fogelman and Wilson, 1960; Wolfman *et al.*, 1963).

A regimen of intraoperative fluid therapy has been advocated in which Ringer-lactate solution is transfused to patients subjected to major surgery in the quantities of 2 litres in the first hour, and 1 litre in every hour thereafter (Terry and Trudnowski, 1964; Trudnowski, 1966). It is postulated that under modern conditions of light anaesthesia this balanced polyionic solution, if given in excess, will be excreted readily by the kidneys (Fieber and Jones, 1967).

The present study is designed to test this hypothesis, and to investigate the changes which occur in urine output, under varying conditions of anaesthesia and surgery in response to the stimulus of a transfusion of 2 litres of Ringer-lactate solution given in one hour. The results are compared with those from a group of patients subjected to major abdominal surgery and transfused in accordance with the principles of the conservative school of fluid therapy.

Materials and Method

Twenty-three patients and six control subjects were chosen for study. The six controls were fit men aged 18 to 45 years with no evidence of renal impairment, who gave informed consent to the study. Each control fasted for 12 hours, was transfused with 2 litres of Ringer-lactate solution in one hour, and remained fasting throughout the experiment. The volume of urine output was measured by voiding at 15-minute intervals for the first hour and at hourly intervals thereafter. Except for an overnight fast and the period of the transfusion, these control subjects were ambulant, but were requested to restrict their activities. In this way the normal urinary response to a 2-litre load of Ringer-lactate solution was determined under fasting conditions similar to that of the patients.

The patients were allocated at random to one of four groups.

Group 1.—This group consisted of six patients aged 38 to 52 years who were subjected to abdominal hysterectomy. Anaesthesia was induced as detailed below, and when the skin was incised an intravenous transfusion of Ringer-lactate solution was begun. Two litres of this fluid was administered in one hour. Patients were catheterized with a self-retaining latex catheter by the surgeon immediately preoperatively. This procedure is a routine part of the preparation for this operation. Urine output was measured in a graduated jar at five-minute intervals during surgery and at hourly intervals for the first eight postoperative hours.

Group 2.—This group consisted of six patients aged 34 to 52 years subjected to abdominal hysterectomy and treated in an identical manner to patients in group 1 except that a slow transfusion of 5% dextrose in water or Ringer-lactate solution was administered.

Group 3.—This group consisted of four patients aged 27 to 35 years who were anaesthetized in the standard manner. They were transfused with 2 litres of Ringer-lactate solution in one hour. Urine output was measured in a manner identical to that used in group 1. In this group, however, no operation was performed until the transfusion was completed, when minor gynaecological procedures were performed. The nature of this experiment was explained to the patients, who agreed to the extension of anaesthesia, the introduction of a catheter, and the transfusion of Ringer-lactate solution. Not unexpectedly, considerable difficulty was experienced in obtaining permission for this work and accounts for the small number of patients in the group.

Group 4.—In this group seven patients aged 24 to 42 who were subjected to abdominal hysterectomy were studied. They were catheterized preoperatively and a diuretic response was induced with 2 litres of Ringer-lactate solution transfused in one hour. Urine output was measured at 5- to 15-minute intervals, in the preoperative and intraoperative period, and at hourly intervals for eight postoperative hours. When the diuresis was definitely established anaesthesia was induced. The surgical incision was delayed slightly until the effect of anaesthesia on the diuretic response was determined. The transfusion was continued in these patients in an attempt to match the urine outflow.

Anaesthesia

Patients were premedicated with 20 mg. of papaveretum and 0.4 mg. of hyoscine one hour before anaesthesia was due to be

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induced. Induction of anaesthesia was achieved with thiopentone 250–350 mg. and suxamethonium 75 mg., and a 9-mm. cuffed oral endotracheal tube was passed. When spontaneous muscular movements appeared patients were paralysed with D-tubocurarine 30–35 mg. and artificial ventilation was maintained with a Howells ventilator (a volume divider). A gas volume of 9 litres per minute, consisting of 35% oxygen and 65% nitrous oxide, was delivered to the patient. Halothane 0.5% was added to the inspired gases.

All patients were free from cardiovascular or respiratory disease. Blood urea concentrations were measured preoperatively and all lay well below 40 mg./100 ml. The operations were performed for non-malignant conditions, usually menorrhagia.

Blood pressure was measured with an upper-arm cuff and a mercury sphygmomanometer, and charted at five-minute intervals throughout the operation. Hypotension was kept to a minimal degree. Patients were placed in the Trendelenburg position with a 5–10 degree head-down tilt. Blood loss was measured by a gravimetric method. Whole stored blood was transfused to those patients who lost more than 400 ml.

Results

The urine output in response to a transfusion of 2 litres of Ringer-lactate solution in one hour given to the control subjects is shown in Fig. 1. A response began in 15 to 45 minutes, reached a peak in an hour, and fell away in two to three hours. This response showed a fairly wide scatter, but the general pattern in each subject was similar.

FIG. 1.—Urine output of six fasting control subjects to whom 2 litres of Ringer-lactate solution was administered in one hour. Vu=rate of urine output in ml./min. Thick black line represents average value. Upper and lower lines represent the standard deviation.

The results obtained from patients in group 1 show that a gross disturbance of the normal pattern of urine output appeared in every patient. Usually some urine was excreted, but in each patient it was scanty and irregular. This irregular pattern of urine output is shown in typical form in Fig. 2. An extreme degree of oliguria which appeared in one patient is depicted in Fig. 3, in which almost complete anuria occurred despite the transfusion. No diuresis occurred in the eight postoperative hours during which these patients were observed.

Patients in group 2 showed a similar scanty and irregular urinary pattern, in general of slightly greater degree than that seen in patients in group 1. A typical urine output pattern for group 2 patients is shown in Fig. 4.

The results obtained from patients in these two groups are shown as average values in the Table. The fluid intake figures refer to the total intraoperative and postoperative fluid volumes, excluding blood. The postoperative urine output occurred in the first eight postoperative hours. These data show that

though a significant increase in the urine output occurred in patients to whom a substantial fluid load was administered ($P<0.001$) this difference bore no relation to the amount of fluid transfused. Patients in group 1 retained large volumes of fluid.

FIG. 2.—Urine output of a representative patient in group 1 to whom 2 litres of Ringer-lactate solution was transfused during an abdominal hysterectomy. FIG. 3.—Urine output of a patient who exhibited the most extreme degree of oliguria in group 1.

FIG. 4.—Urine output of a representative patient from group 2. FIG. 5.—Urine output of a patient in group 3, in whom the response to a transfusion of Ringer-lactate solution in one hour was inhibited by anaesthesia.

The full significance of these results is not apparent when average values are examined, and a more realistic assessment of the sequence of events which were observed in this investigation can be made only by examining the results in individual patients. The results from patients in groups 3 and 4 do not lend themselves to tabulation and statistical analysis.

Results in Groups 1 and 2

	Fluid intake	Urine output		
		Intra-operative	Post-operative	Total
Group 1	3,445 ± 547	66 ± 55	331 ± 70	397 ± 85
Group 2	778 ± 326	19 ± 5	224 ± 58	246 ± 54

Average values in ml. ± standard deviation of fluid intake, excluding blood, and urine output for patients in groups 1 and 2.

Two patients in group 3 who had a transfusion of Ringer-lactate solution, anaesthesia, and minimal surgery showed a urine output pattern indicating that inhibition of the urinary response had occurred. In these two patients virtual anuria occurred throughout most of the period of anaesthesia and no diuresis occurred in the next three postoperative hours. One of these results is shown in Fig. 5. One patient in this group had a response to the transfusion which could be interpreted as normal, and the other showed a response which was probably modified (Fig. 6).

FIG. 6.—Urine output of a patient in group 3 in whom a response to a 2-litre transfusion of Ringer-lactate solution was probably modified by anaesthesia. FIG. 7.—Urine output from a patient in group 4 in whom a preoperative diuresis was induced. The rate of urine flow can be seen to diminish when anaesthesia was induced and to assume a low irregular pattern similar to that seen in Fig. 2 when surgery was begun.

The results obtained from patients in group 4 were more variable. In two patients induction of anaesthesia was accompanied by a fall in the rate of urine output, and the start of surgery produced the irregular pattern similar to that seen in group 1. The results obtained from one of these patients is

shown in Fig. 7. In two patients the rate of urine output continued to rise when anaesthesia was induced but fell to near the zero line when the abdominal wall was incised. The result from one of these patients is shown in Fig. 8. In another patient a grossly irregular rate of urine output appeared when anaesthesia was induced. When surgery was begun the rate fell but never quite to the zero line, and a good though irregular rate of urine production was maintained throughout. This result is shown in Fig. 9. In the remaining two patients anomalous results were obtained concerning the effects of anaesthesia on urine output, but the commencement of surgery was accompanied by the appearance of a low urinary output pattern similar to that seen in Fig. 2.

FIG. 8.—Urine output from a patient in group 4 in whom a preoperative diuresis was induced. The rate of urine flow continued to rise when anaesthesia was induced, but assumed a low irregular pattern similar to Fig. 2 when surgery was begun, despite a continuing and substantial infusion of fluid. FIG. 9.—Urine output from a patient in group 4 in whom a preoperative diuresis was induced. The rate of urine flow became grossly irregular when anaesthesia was induced. The commencement of surgery was rapidly followed by the appearance of a good but relatively low irregular rate of urine output.

Discussion

The results of this investigation show that urine output, in response to a transfusion of 2 litres of Ringer-lactate solution administered in one hour, was altered in two patients by an orthodox technique of light anaesthesia, and by major surgery in all patients studied. This alteration amounted to almost complete inhibition of urine output in some patients subjected to abdominal hysterectomy.

Patients who were anaesthetized and had minimal trauma inflicted showed an unexpected lack of response to the trans-

fusion in two instances, a moderately altered response in another, and a response which was probably normal on only one occasion. Most patients in whom a diuresis was induced with the standard transfusion showed some alteration of this response when anaesthesia was induced. The commencement of surgery was accompanied in all patients by the low irregular pattern of urine output typical of patients in group 1. A comparison of the urine output between patients in groups 1 and 2 shows that a slightly increased urine output usually occurred in patients to whom a substantial transfusion was administered. This difference was small, however, and bore no relation to the differences in the quantities of fluid transfused. Patients who were transfused with large quantities of fluid retained large quantities.

These results are rather different from those obtained by other workers in this field, who concluded that hydrated patients would sustain a diuresis during surgery (Barry *et al.*, 1964). Fieber and Jones (1966) found urine output during and after surgery to be directly proportional to the amount of fluid transfused. They used 5% dextrose in Ringer-lactate solution, and found that urine output paralleled a rising blood sugar, but were satisfied that it was impossible to overtransfuse patients.

The present investigation shows that the normal response to a transfusion of Ringer-lactate solution was inhibited by anaesthesia alone in some instances, and by surgery in all the patients studied, and indicates that overtransfusion could easily have occurred.

One of us (J. R. D.) has observed a patient to whom a considerable quantity of Ringer-lactate solution had been transfused during a gastroenterostomy. Owing to a surgical emergency this patient's abdomen was reopened four hours postoperatively. The stomach, small bowel, and mesentery were found to be grossly oedematous. A similar observation has been made elsewhere (Fieber and Jones, 1966), and this suggests that excess fluid transfused during surgery may sometimes be sequestered in the splanchnic area.

The original observation that fluid retention occurred during surgery was made in patients anaesthetized by a relatively primitive open ether method (Pringle *et al.*, 1905), and was easy to discount on the grounds of general metabolic depression. More recently the phenomenon of salt and water retention during and after surgery was demonstrated in more acceptable conditions (Le Quesne and Lewis, 1953) and a phase of "primary water retention" identified. This phase occurred during the first 24 postoperative hours and was characterized by the excretion of urine of low volume and high specific gravity. These qualities suggested that antidiuretic hormone was responsible for this phase. Later the presence of antidiuretic activity in human urine after surgical operations was convincingly shown in hypophysectomized rats (Eisen and Lewis, 1954). Dudley *et al.* (1954) also produced evidence that an antidiuresis occurs during and after surgery, by transfusing 5% dextrose in water to subjects and patients.

The present investigation shows that a similar antidiuresis occurred in patients transfused with substantial volumes of isotonic polyionic salt solution. This antidiuretic activity appeared within minutes of the skin incision and was intense enough to inhibit an established diuresis. Also, while some antidiuretic hormone was known to be released by anaesthesia, the failure of two patients to respond to transfusion when they were anaesthetized by an orthodox light technique was unexpected. In summary these results show that a major defect of salt and water homeostasis occurred during the surgical procedures under study.

Recent attempts to confirm the observation of a large decrease in interstitial fluid volume after trauma have failed (Virtue *et al.*, 1966; Anderson *et al.*, 1967; Roth *et al.*, 1967; Shizgal *et al.*, 1967; Albert *et al.*, 1968; Reid, 1969). It would appear that the fluid shifts detected by single sampling dilution

techniques were artifacts of the experimental method. Thus the practice of transfusing substantial quantities of Ringer-lactate solution during surgery is deprived of its logical basis.

The interest generated by the recent controversy has, however, focused attention on the present unsatisfactory state regarding intraoperative fluid replacement. Patients subjected to major elective surgery may be fasted for 12 hours preoperatively and at least the same time postoperatively. Fluid exudates have long been known to occur into traumatized tissue and will be a source of fluid loss (Beard and Blalock, 1931). The appearance of albumin in the urine postoperatively (Evans and Enderby, 1952), and its relation to quantities of transfused fluids (MacBeth and Pope, 1968), is an interesting observation which deserves attention. It may be associated with the high incidence of renal failure which has been shown to be a frequent complication of surgery in jaundiced patients, and which can be prevented by a mannitol-induced diuresis (Dawson, 1968).

The selection of Ringer-lactate solution as a fluid suitable for use during surgery is logical enough, but the present investigation indicates that the administration of excessive quantities may not be accompanied by a diuresis adequate to restore normal salt and water balance.

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