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Prevention of Postoperative Pulmonary Edema on the Ward by Application of a Central Venous Pressure Rule§

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Abstract: *Objective*: to demonstrate the efficacy of a Central Venous Pressure rule and algorithm in the elimination of postoperative pulmonary edema after major surgery.

Background: Pulmonary edema in the postoperative period after major surgery is a life-threatening complication, usually due to fluid overload. Analysis of its pathogenesis in our patients during the period 1981 – 1988 led to the formulation of the central venous pressure (CVP) rule in 1990. The purpose of this study was to examine whether this rule had proven to be efficient in preventing pulmonary edema without causing complications related to fluid restriction.

Methods: A retrospective study was performed in our Department about the prevalence of pulmonary edema, venous thrombosis and renal insufficiency during the postoperative period in patients undergoing major abdominal surgery. Any postoperative CVP value above +5 cmH_2O led to a slowdown of supportive IV fluid lasting until a pressure of ≤ +5 cm H_2O was reached, unless the measurement was proven to be wrong or another cause for the high CVP value could be diagnosed. During the first period between January 1981 and December 1988, 415 patients were cared for without application of the CVP rule. During the period between January 1992 and August 2002, 682 patients had postoperative care according to the CVP rule. The results in both periods were compared.

Results: Whereas during the first period 12 cases of pulmonary edema were deplored, no pulmonary edema did occur during the second period. No significant difference in prevalence of venous thrombosis or renal insufficiency was found.

Conclusions: The CVP rule is a safe and very efficient method to prevent fluid overload and pulmonary edema on a surgical ward after major abdominal surgery. Training in correct CVP measurement through the central venous catheter and good collaboration between doctors and nursing staff is a prerequisite for success.

INTRODUCTION

Pulmonary edema in the postoperative period may be due to left ventricular failure or injury to the pulmonary alveolar membrane, but most frequently it is the result of circulatory overload following excessive intravenous (IV) fluid administration [1-4]. If pulmonary capillary hydrostatic pressure rises, fluid leaks out of the capillaries and enters the alveolar compartment once the capacity of the lymphatics is overwhelmed [5].

Auscultation of the lungs and increased respiratory rate allow the diagnosis of pulmonary edema, but central venous pressure (CVP) measuring is necessary to obtain information about circulating volume status and cardiac function, in order to prevent full blown pulmonary edema. Monitoring of the CVP is very useful as a practical guide for fluid therapy [6]. Although surgeons and residents are very well aware of these basic principles, it is common knowledge that pulmonary edema by fluid overload may occur on surgical wards. After a period of analysing our cases, a CVP rule was developed in 1990 – 1991 by the senior author and strictly applied thereafter on the ward, by nursing and medical staff combined: the CVP had to be maintained under the value of 5 cm H_2O.

The purpose of this study was to evaluate the effectiveness of this rule in the prevention of pulmonary edema on the ward in the postoperative period following major surgery. Furthermore, its safety and applicability were examined in detail.

PATIENTS AND METHODS

1. The CVP Rule

The CVP rule dictates that whenever the postoperative CVP measurement indicates a value above +5 cmH_2O, the rate of fluid administration should be halved immediately and lowered to the minimal rate if the next measurement, 6 hours later, still reports a value above +5 cmH_2O. This policy of fluid restriction has to be continued until a value of ≤ +5 cmH_2O has been obtained. The administration of furosemide should be considered if CVP remains elevated after 12 hours of fluid restriction. The algorithm of this rule is represented in Fig. (**1**).

2. Patient Population

All 1097 patients, older than 16 years, who underwent major abdominal surgery for cancer in the Department of Surgical Oncology during two defined periods, were included. The prevalence of pulmonary edema was studied and

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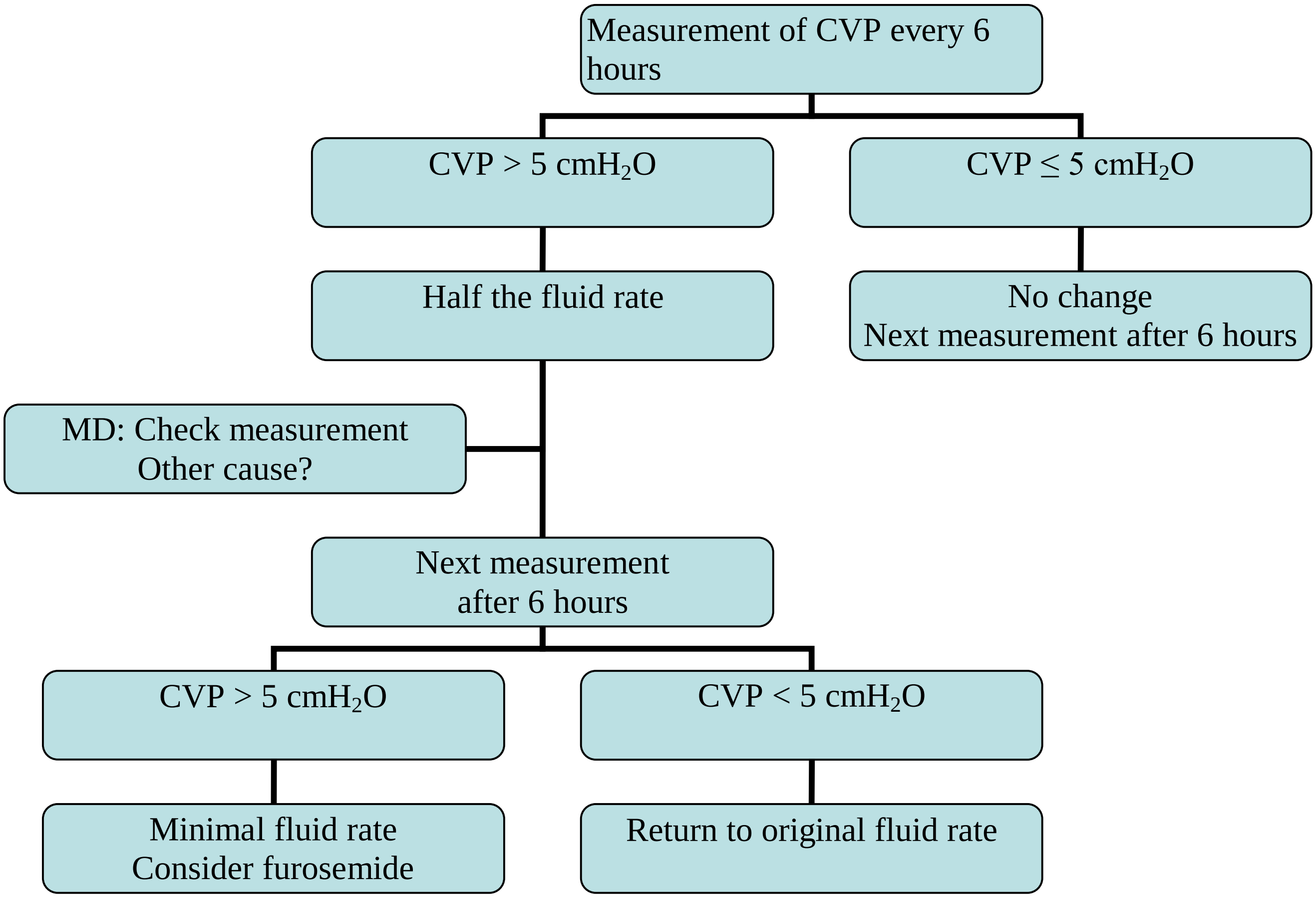

Fig. (1). Algorithm of the CVP rule.

compared between two periods. The first group included the 415 patients, mean age of 57.2 years, operated upon between January 1981 and December 1988: the period before the CVP rule. The second group concerned 682 patients, mean age of 57.1 years, who underwent surgery between January 1992 and August 2002: a ten-year period during which the CVP rule was applied consistently. Most patients had major abdominal operations involving an important loss of fluid during surgery and usually necessitating a peroperative replacement of several liters. They all had a central venous catheter placed by the anaesthesiologist after induction. After a short stay in the Intensive Care Unit for some patients, they all were cared for on the surgical ward by the nursing staff and two surgical residents in training under the supervision of two staff members. The standard daily amount of IV fluid prescribed was 2.5 liters of glucose and electrolyte solution, containing 154 mmol/L of Sodium and Chloride or 2.5 liters of total parenteral nutrition. In the first period corrections were made based on in and out balance and on sporadic CVP measurements. In the second period the CVP rule was applied. Since 1989 all patients received a prophylactic dose of Low Molecular Weight heparine subcutaneously from the evening before surgery until discharge.

3. CVP Measurement

Postoperatively, on the ward, the patient's central line was connected to a manometer column, filled with saline, assembled at the bedside. A 3-way stopcock was inserted to allow easy flushing of the line and avoid even tiny air bubbles.

The technique used to measure the CVP was the classical one [6, 7]. The patient is placed in the supine position and the zero mark on the manometer column is set at the level of the patient's tricuspid valve. Clinically this point correlates with the midaxillary line of the patient or with a point located 5 cm below Louis' angle being the junction between the sternum and the second rib. Before each CVP measurement, the manometer column should be zeroed again at this level. The stopcock then is turned to fill the manometer up to 25 cmH_2O. When the stopcock is opened to the patient, the water column will gradually descend and should stabilize before the reading is made. It is important that the patient is relaxed and breathing normally.

This CVP measurement was performed by the nurses every 6 hours as long as patients were depending on IV fluid or parenteral nutrition. The measured values were registered in the nursing file, together with other important parameters such as temperature, pulse rate, blood pressure, respiratory rate, urinary output and other fluid losses.

4. Methods

The medical and nursing files of all patients included in the study, were scrutinized retrospectively for all postoperative complications and more specifically for pulmonary edema, venous thrombosis and renal insufficiency. The application of the CVP rule was studied in detail in the group of patients who underwent cytoreductive surgery for ovarian cancer during the second period. In this patient group all

CVP measurements were analyzed as well as the amount of fluid administered daily and the urine output obtained.

Pulmonary edema was defined as acute respiratory distress requiring emergency medical intervention, and transportation of the patient to an intensive care unit with intubation and temporary ventilation for which no other cause than fluid overload could be found. Venous thrombosis was defined as thrombosis with clinical symptoms, confirmed by Doppler ultrasound. Renal insufficiency was defined as a permanently increased serum creatinine value.

Table 1. Patients and Types of Surgery

	1981 - 1988 (Before CVP Rule)	1992 - 2002 (After CVP Rule)
Total Number of Patients	415	682
Female	290	451
Male	125	231
Age	57.2 y (17-91)	57.1 y (16-88)
Cytoreduction for Ovarian Cancer	155	113
Cytoreduction for Other Tumors	26	112
Retroperitoneal Node Dissections	12	52
Retroperitoneal Tumors	23	71
Splenectomy (Large Spleen)	16	41
Adrenalectomy (Large Tumors)	9	14
Gastrointestinal Cancers	112	159
Pelvic Surgery	41	61
Pelvic Exenteration	16	50
Liver Resection	5	9

Table 2. Result of CVP Rule

	1981 - 1988 (Before CVP Rule)	1992 - 2002 (After CVP Rule)	X^2 Statistics
Number of Patients	415	682	
Pulmonary Edema	12 (2.9 %)	0	$p < 0.0001$
Renal Insufficiency	6	7	$p = 0.73$
Deep Venous Thrombosis	3	4	$p = 0.90$

RESULTS

A total of 1097 patients were included in the study: 415 from the 1981 – 1988 period and 682 patients from the 1992 – 2002 period. All patients had undergone major abdominal surgery for oncological pathology as indicated in Table **1**. Major types of surgery performed were extensive cytoreductive surgery for ovarian cancer or other indications, colorectal resections, pelvic exenterations for recurrent gynaecological or rectal cancer, resection of retroperitoneal sarcomas and retroperitoneal node dissections. Compared to the first period, less ovarian cancers were operated during the second period; in turn a larger number of cytoreductive surgery for other tumors, pelvic exenterations and resection of retroperitoneal tumors were performed. The age and gender distribution of patients in both periods was similar.

The dramatic effect of the implementation of the CVP rule is documented by the results of our study as shown in Table **2**. In the period before the implementation of the CVP rule, 12 patients (2.9%) had to be rescued from pulmonary edema while no patient suffered this complication in the second period of ten consecutive years. Although pulmonary edema might be caused by other mechanisms than circulatory fluid overload (eg. allergic reaction, shock, disseminated intravascular coagulation, uremia) all cases of pulmonary edema observed in our study were caused by fluid overload. No significant difference in prevalence of renal insufficiency or venous thrombosis in both patient groups could be found. Further analysis of these complications revealed preoperative chemo- or radiotherapy and sepsis as causes of renal insufficiency. Venous thrombosis could be explained by tumour compression on major veins and/or surgical dissection of these veins and/or as a paraneoplastic phenomenon. In no single patient dehydration could be discovered as a possible cause of these complications. All other complications in both patient groups were analyzed, but no significant differences were found in their number or type and therefore these results were not retained in this report.

During the second period the application of the CVP rule led to adjustment of fluid administration rate in about one fourth of the patients. To illustrate this, a more detailed study was made on the 113 patients who underwent cytoreduction for ovarian cancer in the second period. This subgroup was chosen because it had proven to be the group of patients with the highest risk for pulmonary edema in the first study period (7 out of 113 patients – 6.2 %). In 12 patients no sufficient information for analysis was available. Only the measurements of CVP taken on the surgical ward are presented in Table **3**. The measurements on the ICU were not taken into account. This explains the difference in the number of patients studied during the first days after surgery. The fall-off from day 5 on is explained by the resuming of oral feeding and the end of IV fluid with removal of the central venous catheter.

The results in Table **3** show that on the first postoperative day 25 % of the patients had a mean CVP value of ≥ 5 cm H_2O and 45 % had at least one value above 5 cm. This proportion diminished progressively during the first week to 10 % patients with a mean value of ≥ 5 cm and 14 % with at least one value > 5 cm at day 6. Interestingly an increased proportion of subjects with high CVP values was registered at day 7 and 8 coïncident with the mean switchover-time from IV to oral feeding.

That the CVP rule was effectively applied in this patient population is proven by the fact that the amount of fluid administered was less than the standard volume prescribed. The median amount delivered was less than 2500 ml on all days and reached values as low as 150, 600 and 500 ml on day 3 to 5 respectively. When comparing the daily amount of administered fluid between patients with a mean CVP value greater than 5 cm H_2O and those with a mean CVP value less than 5, a statistically highly significant difference was found.

Table 3. Detailed Analysis in 101 Ovarian Cancer Patients

Day Postop.	Number of Patients with CVP Values *	Number of Patients with at Least One Value > +5 cm H_2O	Number of Patients with Mean CVP $\geq$ +5 cm H_2O	Amount of IV Fluid Administered Median (Range)	Urine Output Median (Range)
1	76	34 (45 %)	19 (25 %)	2369 (1000-3500)	1986 (550-4300)
2	90	38 (42 %)	22 (24 %)	2351 (1000-3500)	2226 (900-4800)
3	96	28 (29 %)	22 (23 %)	2128 (150-3000)	2203 (500-5000)
4	93	20 (22 %)	12 (13 %)	2182 (600-3700)	2309 (500-4400)
5	82	9 (11 %)	9 (11 %)	2224 (500-3000)	2245 (800-4600)
6	63	9 (14 %)	6 (10 %)	2372 (1000-3500)	2008 (700-6300)
7	49	10 (20 %)	2 (4 %)	2281 (500-3000)	2181 (500-5700)
8	41	2 (5 %)	5 (12 %)	2400 (1000-3500)	2072 (1100-3700)
9	31	2 (6 %)	1 (3 %)	2125 (1000-2500)	2060 (650-3450)
10	23	1 (5 %)	3 (13 %)	1900 (1000-2500)	1895 (700-3500)

(X^2 statistics: $p<0.0001$) Patients with a CVP value of more than 5 cm received less fluid than patients with a CVP value of less than 5, proving that the CVP-rule was applied affectively.

During this same period, despite a drastic reduction of IV fluid volume administration, the median daily urinary output remained around 2200-2300 ml with lowest values of 500 ml, but also high values up to 5000 ml. A value between 500 ml and 800 ml urine output over 24 hours was noticed 15 times over the first 10-day period, but in 14 different patients. In Fig. (**2**) the central venous pressure evolution, the amount of fluid administered and the urinary output are shown over the first 10 postoperative days. It illustrates that although the median values of CVP, IV fluid administered and urinary output are as expected, the maximum and minimum values are surprisingly deviating from expected "standard" quantities because of individual adaptations made as a consequence of the CVP rule. This effect is still visible at day 8.

DISCUSSION

Very few studies have been dedicated to fluid overload and pulmonary edema in the postoperative period and to their to prevention on a surgical ward. However there is little doubt that these problems occur and that their incidence is higher than commonly accepted. According to retrospective studies, incidences of 3 % [8], 7 % [9] and 7.6 % [4] have been found. In a prospective randomized study comparing two types of fluid regimes Brandstrup [10] found an incidence of 5 % in the standard fluid arm.

In a survey of consultant surgeons [11] 54 % of the respondents agreed that salt and water overload frequently caused significant complications in postoperative patients. 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. Compared to these figures our incidence of about 3 % in the period 1981-1988 certainly can be considered acceptable and indicative of prudent management and care of the patients.

Several synergistic mechanisms can lead to postoperative fluid overload. During the procedure itself the anaesthesiologist has to keep the intravascular volume at an optimal level in order to assure adequate organ perfusion. During the first postoperative days excretion of fluid and salt is deficient. While there are no reliable clinical signs of fluid overload, most surgical departments rely on "standard" prescriptions of fluid and salt, usually derived from resuscitation protocols.

There are many reasons for intra-operative administration of large quantities of fluids during major surgery and even in a recent study of a restricted peroperative fluid protocol [8] the target CVP value was +/- 15 mmHg. But as Holte wrote in 2006 [12] it has not been uncommon to see very large amounts of fluid administered, based on application of goal-directed resuscitation in order to achieve supranormal circulatory function guided by hemodynamic monitoring protocols developed in the 70's an 80's. When patients are weighed after the operation, an increase in body weight of 3 to 10 kg has been found [13] and Brandstrup stated in 2006 [10] that current fluid administration-schemes cause a weight gain of 3 to 7 kg.

In the 1980's the standard prescription consisted of 3L fluid and 154 mMol of sodium per day. This was applied in most centres and is still continued nowadays [14]. As found in a survey by Lobo [11] many surgeons preferred their juniors to err on the side of fluid over-replacement. Most doctors and nurses are afraid of giving too little fluid to postoperative patients. This is probably influenced by teachings on the management of hypovolemic patients [11]. However already in the first period of our study the standard prescription included only 2.5L fluid and 154 mMol of sodium per day in our department.

Several studies have established that postoperative patients have a reduced capacity to excrete excess sodium and water [14], but this problem is not well known [11]. The endocrine response to trauma leads to conservation of sodium and water, and to excretion of potassium by the mediation of antidiuretic hormone, aldosterone and the renin-angiotensin II system [12]. Since there are no volume receptors in the interstitial space, the kidney will be completely

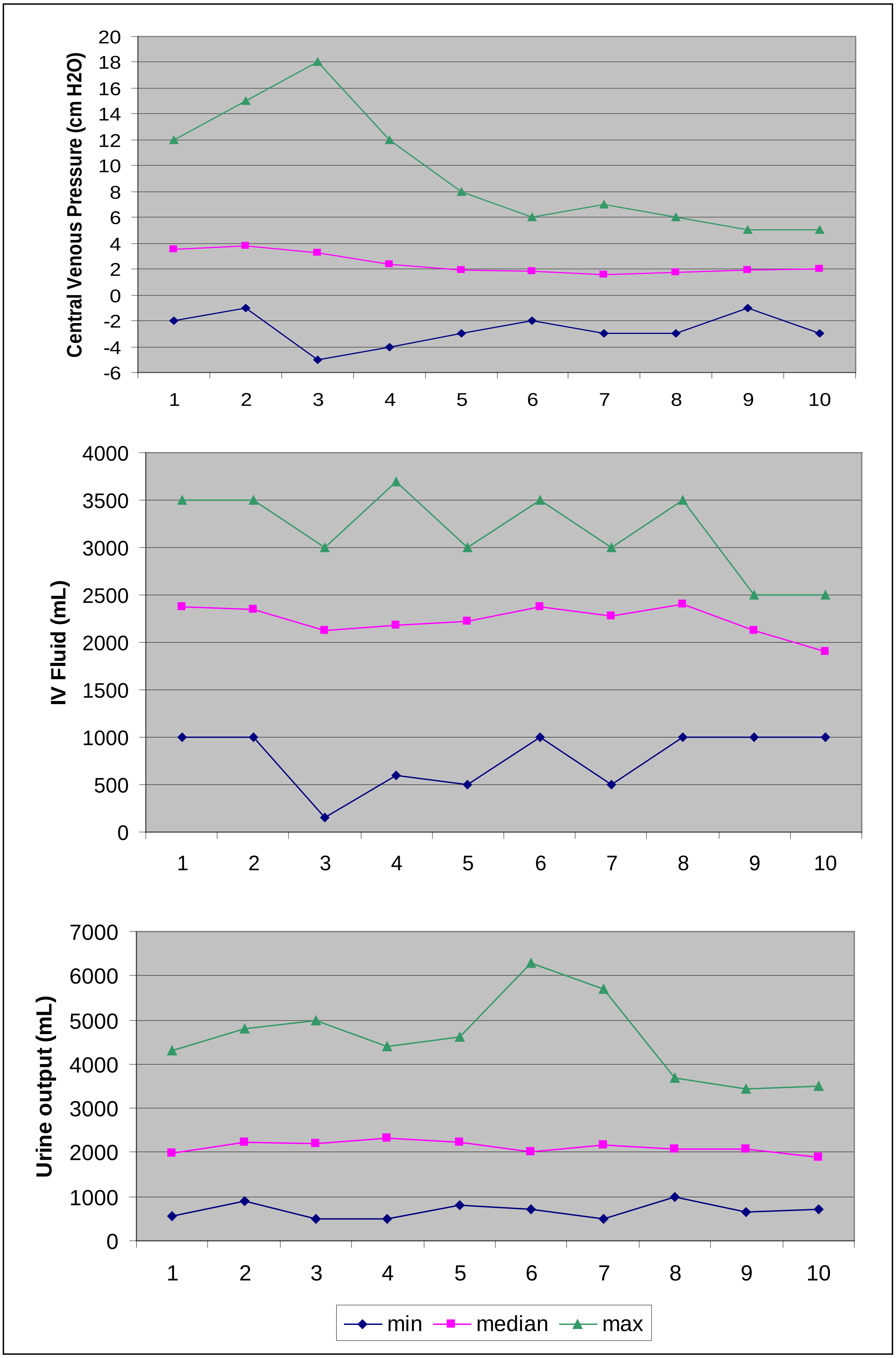

Fig. (2). Evolution of CVP, IV fluid and urine output during first 10 days on the ward. A detailed study of Central Venous Pressure, amount of IV fluid administered and urine output in 101 patients with ovarian cancer. The figure summarizes the median value, as well as the maximum and minimum values registered on each of the first 10 days after surgery. The figure on de X-axis indicates the postoperative day.

Table 4. Causes of Fluid Overload Before the Introduction of the CVP Rule

Doctors	Nurses
Standard daily prescription of 2.5 liters	Correct administration
Fluid added for medication unknown	Quantity known but not always recorded
Shift from third space unknown	Unknown
Clinical appearance considered more reliable than CVP value	Clinical appearance considered more reliable than CVP value
No standard orders for CVP measurement	Sporadic measurements
No precise normal CVP values known	No precise normal CVP values known
Doubt about reliability of measurement	Expect a check by the doctor
No well defined action plan when CVP value increases	Expect clear instructions

No reliable signals from the patient; signs of fluid overload not detected.

ignorant of even massive edemas [15]. The only method to quantify the amount of fluid sequestrated in the third space is to weigh the patient, but this is not often practiced on surgical wards. Of course, fluids in the third space return to the vascular compartment several days after surgery [4], leading to a kind of auto-injection of IV fluid.

Virtually all protocols for postoperative fluid management recommend frequent monitoring of the patient's volume status utilizing clinical parameters such as blood pressure, heart rate, urine output, auscultation of the lungs, calculation of the fluid balance based on in-and output data [4]. If excessive fluid retention is noted, the rate of fluid administration can be decreased. But IV fluid prescription is usually left to the responsibility of the most junior doctor in many teams [11] and surgical staffs do not always use the available fluid balance information when prescribing [9]. Moreover the fact remains that in healthy individuals, pulmonary edema may be the initial clinical manifestation of fluid overload [4].

In the 80's we deplored 1 or 2 patients a year who had to be rescued from pulmonary edema despite what was considered good postoperative care. For this reason an in-depth analysis of these cases was performed and a limited number of factors was identified as responsible for the development of this life-threatening complication. In Table **4** these elements are summarised both from the viewpoint of the medical doctors as well as that of the nurses. A careful consideration of these elements is worthwhile.

The standard amount of IV fluid prescribed by the surgical residents was 2.5 litres for the next 24 hours. The nursing staff considered it to be their duty to administer this fluid as precisely as possible over this period of time. Of course, for many patients medications such as analgesics, antibiotics and antipyretics were prescribed as well. Whereas the nursing staff was very well aware of the extra fluid needed to dissolve these medications before IV injection, the surgical staff usually ignored this problem, and if asked for, they underestimated seriously this extra amount of fluid given. Another unknown factor was the fluid shift from the third space back to the IV compartment. Currently there are no reliable methods to measure the amount of fluid which shifts into this space during and within the first 5-6 hours after the operation, but it can amount to several litres in major abdominal operations [10]. Analogous to the situation after major burns, this fluid progressively returns to the intravascular compartment, starting about 48 hours after surgery when the inflammatory reaction decreases [16]. This fluid has to be considered an invisible internal infusion on top of the external IV therapy. In our retrospective analysis it turned out that residents as well as nurses had put more trust on the clinical appearance of the patient than on the value of the CVP measurement. Of course it is well known that there are no obvious clinical signs of fluid overload till the start of pulmonary edema causing dyspnoea, orthopnoea, pink frothy sputum, basal crepitations and gallop rhythm [3]. The patient himself is unable to give any warning signal of fluid overload. It is only CVP or weight measurement that allows an earlier diagnosis of fluid overload.

Table 5. Causes of Unreliable CVP Reading

- Malposition of the tip of the central venous catheter, outside the distal segment of the superior vena cava on chest X-ray
- Thrombosis at the tip of the catheter with blood withdrawal hindrance
- Wrong reference zero point
- Coughing, straining of the patient
- Small air bubbles in the circuit

In accordance with this clinical attitude there were no standardized prescriptions for interpreting CVP measurements and for making adequate decisions based on these data. Although all of these patients had a central venous catheter, it was left to the decision of the attending doctors and of the caring nurses when and how often CVP had to be measured. Moreover, some ambiguity remained about “normal” or “acceptable” values. No sharp limits were present in the mind of the residents and no clear upper limit was set in the Department. Another hurdle was the fact that a high CVP value was sometimes considered as unreliable, ascribed to "inexperienced nurses" or to a "possible malposition of the catheter" without adequate check by the doctor or confirmation by chest-X-ray. Therefore, high CVP values were sometimes easily accepted by residents and the nurses were not in the position to challenge this. Finally a rather high CVP value did not always lead to a timely and adequate intervention. Not always was the quantity of fluid diminished or were diuretics prescribed. One possible reason was a long lasting day in the operating theatre for the surgical staff. It turned out in this retrospective study that the pulmonary edema always had been preceded by increased CVP values during 24 to 48 hours without adequate intervention. Of course young patients with excellent cardiac and renal function can adapt to fluid volume excess by increased urinary output. But especially elderly patients or patients with decreased renal or cardiac function, or with intercurrent infection might be unable to cope with fluid overload.

All these elements led to the choice of a rigid procedure that had to be applied strictly by the nurses and doctors as well. The tolerable upper value of "normal" CVP was set at a safe +5 cmH_2O. No exception to the rule was allowed, except if convincing proof could be given that the measured value was incorrect or unreliable (see Table **5**), or was due to another cause than fluid overload (Table **6**). The fear that by application of this rule some patients might have become dehydrated has not been confirmed. No increase in venous thrombosis or renal insufficiency was noted.

Table 6. Causes of High CVP Values

- Fluid overload
- Increased intrathoracic pressure
- Cardiac decompensation
- Pulmonary embolism
- Pericardial tamponade
- Constrictive pericarditis
- Superior vena cava thrombosis
- Stenosis of pulmonary artery
- Pulmonary hypertension

More recently several publications have drawn attention to the danger of fluid overload and of giving too much sodium and chloride in the peroperative as well as in the postoperative management. Lobo [17] stresses that the aim of the administration of parental fluid should be clearly defined: is it for resuscitation, replacement of abnormal losses or maintenance of basic needs? Fluid balance charts should be used, but the inherent inaccuracies about the fluid volume in the third space and the estimation of insensible loss should be remembered [18]. Brandstrup [10] proposes body weight measurements as the most reliable tool and guide for perioperative fluid administration. Fearon [19] proposes to take the IV drip down as soon as possible. Lobo [17] believes that better training and education of doctors and nurses is the key, that specialists should play a more active role and that there should be written guidelines, but also some method of ensuring that these guidelines are read and followed. We are unaware of a study demonstrating the efficacy of these measures on a surgical ward. The recent trend of giving less fluid and sodium to patients in the perioperative period certainly will diminish the risk of fluid overload [20]. Nevertheless there will always be more difficult situations such as important blood loss and long duration of surgical interventions much more complex than elective colonic resections studied in fast track surgery protocols. Postoperatively fluid management may be complicated by factors such as gastrointestinal complications, inability of oral feeding, sepsis and cachexia or by limited cardiac or renal function.

We are well aware of the limitations of this retrospective study over a longer period and other factors might have contributed to the elimination of pulmonary edema. One obvious difference was the use of low molecular weight heparin in the second period, but we are unaware of any report that this should prevent pulmonary edema.

There are more reliable measures of fluid volume status than central venous pressure such as echocardiography, urinary sodium or pulmonary capillary wedge pressure, but these methods are not suitable for daily use on a surgical ward. On the other hand most patients undergoing major surgery have a central venous catheter.

Our experience as documented in this study has convinced us that the CVP rule offers a very reliable, effective and feasible solution to the problem of fluid overload and pulmonary edema on the surgical ward. The value of the central venous pressure is the result of an interaction between the intravascular volume, the function of the heart, the vasomotor tonus and the intrathoracic pressure. This value gives the clinican a parameter that integrates intravascular volume resulting from "known" and "unknown" parenteral infusion, internal infusion by fluid returning from the third space, cardiac performance of this individual patient with his variable ability to excrete water and salt.

The alarm value set at +5cm H_2O pressure was very effective in all patients and did not lead to complications possibly related to under filling and dehydration. The CVP rule has the advantage of simplicity, reliability and reproducibility and does not depend on cumbersome fluid balance calculations and estimation of insensible loss. It allows to correct very fast and in a simple way inadequate prescriptions of fluid and sodium, whether "standard" or individualized. It provides doctors and nurses an objective parameter to guide the fluid therapy in the individual patient.

CONCLUSION

Although limiting fluid and sodium administration as well as education and guidelines certainly are very valuable we recommend this CVP rule and algorithm as a most efficient measure to eliminate fluid overload and pulmonary edema after major and complicated surgery. Its efficacy depends on a good collaboration between the medical and the nursing staff. Nurses as well as doctors should learn how to measure correctly the central venous pressure through the central venous catheter. It is essential that the doctor should control the measurement if a value of above +5 cm H_2O is found by the nurse and excludes causes of CVP elevation other than fluid overload. The protocol should be strictly followed by doctors as well as by nurses and no deviation should be allowed.

REFERENCES

[1] Cooperman LH, Price HL. Pulmonary edema in the operative and postoperative period: A review of 40 cases. Ann Surg 1970; 172: 883-91.

[2] Brismar B, Franksson C, Sundelin P. Respiratory distress syndrome - A result of disseminated intravascular coagulation (DIC) or of fluid overload. Acta Chir Scand 1980; 146: 145-8.

[3] Lowell JA, Schifferdecker C, Driscoll DF, *et al.* Postoperative fluid overload: Not a benign problem. Crit Care Med 1990; 18: 728-33.

[4] Arieff AI. Fatal postoperative pulmonary edema: Pathogenesis and literature review. Chest 1999; 115: 1371-7.

[5] Guyton AC, Lindsey AW. Effect of elevated left atrial pressure and decreased plasma protein concentration on the development of pulmonary edema. Circ Res 1959; 7: 649-57.

[6] Roberts JR, Hedge JR, Clinical procedures in emergency medicine. 3rd ed. US, WB Saunders, 1998; chap 24.

[7] Sheppard M. Reading central venous pressure – 1. Nursing Times 2000; 96: 43-4.
[8] Nisanevich V, Felsenstein I, Almogy G, *et al.* Effect of intraoperative fluid management on outcome after intraabdominal surgery. Anesthesiology 2005; 103: 25-32.
[9] Walsh SR, Walsh CJ. Intravenous fluid-associated morbidity in postoperative patients. Ann R Coll Surg Engl 2005; 87: 126-30.
[10] Brandstrup B. Fluid therapy for the surgical patient. Best Pract Res Clin Anaesthesiol 2006; 20: 265-83.
[11] Lobo DN, Dube MG, Neal KR, *et al.* Peri-operative fluid and electrolyte management: a survey of consultant surgeons in the UK. Ann R Coll Surg Engl 2002; 84: 156-60.
[12] Holte K, Kehlet H. Fluid therapy and surgical outcomes in elective surgery: A need for reassessment in fast-track surgery. J Am Coll Surg 2006; 202: 971-89.
[13] Lobo DN, Bostock KA, Neal KR, *et al*. Effect of salt and water balance on recovery of gastrointestinal function after elective colonic resection: a randomised controlled trial. Lancet 2002; 359: 1812-8.
[14] Tambyraja AL, Sengupta F, MacGregor AB, *et al.* Patterns and clinical outcomes associated with routine intravenous sodium and fluid administration after colorectal resection. World J Surg 2004; 28: 1046-52.
[15] Aukland K, Nicolaysen G. Interstitial fluid volume: Local regulatory mechanisms. Physiol Rev 1981; 61: 556-643.
[16] Redden M, Wotton K. Third-space fluid shift in elderly patients undergoing gastrointestinal surgery Part I: Pathophysiological mechanisms. Contemporary Nurse 2002; 12: 275-83.
[17] Lobo DN, Macafee DAL, Allison SP. How perioperative fluid balance influences postoperative outcomes. Best Pract Res Clin Anaesthesiol 2006; 20: 439-55.
[18] Lobo DN. Fluid, electrolytes and nutrition: physiological and clinical aspects. Proc Nutr Soc 2004; 63: 453-66.
[19] Fearon KCH, Ljungqvist O, Von Meyenfeldt M, *et al.* Enhanced recovery after surgery: A consensus review of clinical care for patients undergoing colonic resection. Clin Nutr 2005; 24(3): 466-77.
[20] MacKay G, Fearon K, McConnachie A, Serpell MG, Molloy RG, O'Dwyer PJ. Randomized clinical trial of the effect of postoperative intravenous fluid restriction on recovery after elective colorectal surgery. Br J Surg 2006; 93: 1469-74.

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