Protection of Renal Function During Surgery of the Abdominal Aorta

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ABSTRACT

The operative and postoperative urinary output of 55 patients who underwent surgery for ruptured abdominal aortic aneurysms, unruptured abdominal aortic aneurysms, and aorto-iliac occlusive disease was recorded. There were five cases of postoperative anuria among 28 patients who received no free fluid in the immediate preoperative period. No case of anuria occurred in 27 patients who received either: (1) a water load of 5% dextrose in water or (2) 20% mannitol solution. The patients who received mannitol had a markedly greater operative and postoperative urinary output.

Intravenous infusion of mannitol is recommended during the preoperative and operative period in patients with ruptured aneurysms of the abdominal aorta.

CONTROVERSY exists over the cause, the frequency of occurrence, and the best method of prevention of the acute renal failure which occasionally follows operations in which the abdominal aorta, below the renal arteries, is temporarily occluded. Aortic occlusion is required during the surgical treatment of an abdominal aortic aneurysm, performed either as an elective procedure or in the treatment of aneurysmal rupture, and in the repair of aorto-iliac occlusion. The purpose of this article is to report our experience with 55 patients who have had operations of this type. In the first 28 patients, only blood loss was replaced: in the second 27 patients, either intravenous mannitol or an equivalent volume of 5% dextrose in water was given throughout the operation.

CLINICAL MATERIAL AND METHODS OF EVALUATION

In the 12-month period prior to September 1961, 28 patients in the Cardiovascular Surgery Division of the Toronto General Hospital received operations in which the abdominal aorta, below the renal arteries, was temporarily occluded: nine for unruptured abdominal aortic aneurysms, seven for ruptured abdominal aortic aneurysms, and 12 for aorto-iliac occlusion. The patients scheduled for elective operation received no fluid during the eight to 12 hours before surgery; the patients with ruptured aneurysms were taken directly to the operating room from the Emergency Department: both groups received whole blood only during their surgery. These 28 patients are designated as Group I. Their charts were reviewed for assessment of the duration of aortic occlusion and the postoperative renal function. As knowledge of their course was obtained from a retrospective review, it is less accurate than that of the following two groups.

In September 1961, the osmotic diuretic, mannitol, became available for routine use. Between September 1961 and June 1962, 27 patients were operated upon: 11 for unruptured abdominal aortic aneurysms, six for ruptured abdominal aneurysms, and 10 for aorto-iliac occlusions. They were divided into Groups II and III. The 13 patients in Group II were given an intravenous infusion of 5% dextrose in water at a standard rate of 500 c.c. every 90 minutes. The 14 patients in Group III were given an equivalent volume of 20% mannitol in 5% dextrose and water. The infusions were started with the induction of anesthesia in the patients who were undergoing elective procedures; in the patients with ruptured aneurysms, they were started as soon as they were seen in the Emergency Department. The infusions were continued until the repair was finished and the clamp on the abdominal aorta removed.

The urinary output was measured on the operating table and every hour for 48 hours postoperatively. The blood urea nitrogen (BUN) was determined daily for three days. The fluid management was the same for both groups; in the first 24 hours, it consisted of no fluid by mouth and 5% dextrose in water intravenously at a rate of 100 c.c. per hour.

Although none of the three groups is strictly comparable as to the type of case (Table I), we believe that they are sufficiently similar to allow some valid comparisons. They were consecutive cases, of the same age group, all operated upon by the same group of surgeons, and the duration of aortic occlusion was similar (Group I, 75 minutes; Group II, 64 minutes; and Group III, 67 minutes). Group III, the group which received mannitol and had the largest postoperative urinary output, contained more patients with ruptured aneurysms and aneurysms subjected to elective operation than did Group II, the group which received only a water load. Several patients in

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TABLE I.—A COMPARISON OF THE DURATION OF AORTIC OCCLUSION, TYPE OF CASE, AND FREQUENCY OF RENAL FAILURE IN THE THREE GROUPS OF PATIENTS UNDERGOING OPERATIONS IN WHICH THE ABDOMINAL AORTA BELOW THE RENAL ARTERIES WAS TEMPORARILY OCCLUDED.

	Group I 1960-61		*Group II* 1961-62		*Group III* 1961-62	
Duration of aortic occlusion	75 min. (range: 35-140)		64 min. (26-150)		67 min. (27-150)	
	Number	*Renal failure*	*Number*	*Renal failure*	*Number*	*Renal failure*
Elective aneurysms	9	0	4	0	7	0
Ruptured aneurysms	7	4	1	0	5	0
Occlusive disease	12	1	8	0	2	0
	28	5	13	0	14	0

whom a clamp was placed on the aorta above the renal arteries or on the renal arteries themselves were excluded from this review.

RESULTS

Five of the 28 patients in Group I died from postoperative renal failure. Four of these patients were being operated upon for ruptured aneurysms and one for aorto-iliac occlusive disease (Table I). Each of the four patients with ruptured aneurysms (ages 66, 75, 75, 72) was either in a state of shock for some time prior to surgery or experienced severe hypotension on release of the aortic clamp. The patient with aorto-iliac occlusion, aged 66, also had a transient period of hypotension during the operation. The postoperative urinary output, obtainable from the charts of 26 of the 28 patients in Group I, averaged less than 500 c.c. during the first 24 hours (Table II).

TABLE II.—A COMPARISON OF THE MEAN URINARY OUTPUT IN THE FIRST EIGHT HOURS AND FIRST 24 HOURS POSTOPERATIVELY IN THE THREE GROUPS OF PATIENTS

	First eight hours	*First 24 hours*
Group I	——	Less than 500 c.c.
Group II	215 c.c.	835 c.c.
Group III	909 c.c.	1613 c.c.

There was only one hospital death in Group II and one in Group III, both from myocardial infarction. No deaths occurred in either group from renal insufficiency. The urinary output was over 400 c.c. in the first 24 hours in every patient in Group III and in all but one of Group II; this patient was the one case of ruptured aneurysm in 1961-62 who had not received intravenous mannitol. Fig. 1 and Table II show the measured urinary output during the first eight hours and the first 24 hours postoperatively in each group. Despite the fact that Group III was heavily weighted with patients with ruptured aneurysms and consequent shock and flank hematomata, the mean urinary output was over four times that of Group II in the first eight hours and almost twice that of Group II in the first 24 hours.

A significant correlation was not obtained between the duration of aortic occlusion and either the eight-hour or 24-hour postoperative urinary volume. The changes in BUN and serum electrolytes were not significant.

It was striking to observe a marked diuresis before or during the operative repair of a ruptured aneurysm in several patients who had been oliguric during their emergency treatment in, and transportation from, a referring hospital. One such patient who was known to be anuric for six hours prior to surgery, had the largest operative and postoperative diuresis in the entire series, following a mannitol infusion.

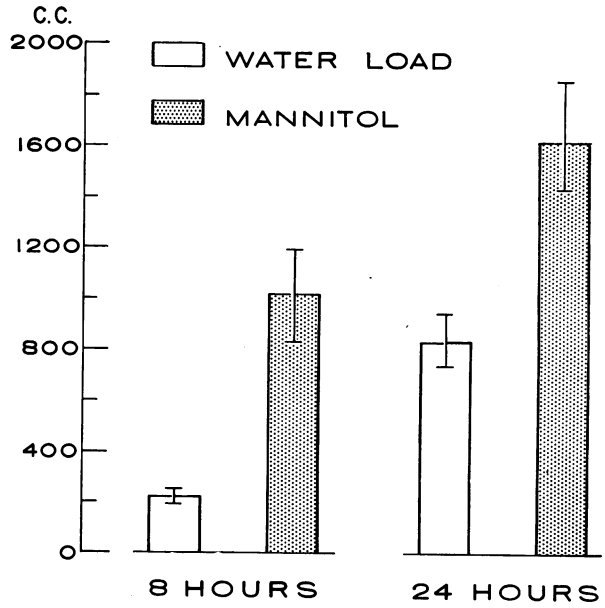

Fig. 1.—The mean urinary output at eight and 24 hours after operation in the 13 patients in Group II who received a water load and the 14 patients in Group III who received mannitol. The standard errors of the means are shown. The difference between the mean outputs at both eight and 24 hours is significant at the 0.1% level ($P < .001$).

In summary, the results of the survey indicated that five of the 28 patients who were managed with blood replacement only, died of anuria. The urinary output of the patients in this group was low during the first 24 hours postoperatively. None of 27 subsequent patients, all of whom received either a water load or a mannitol infusion, died of renal failure. Only one patient had a urinary output of less than 400 c.c. in the first 24 hours. The patients who had received mannitol had a much higher urinary output than those who had received 5% dextrose in water, despite the fact that the group receiving mannitol included many more patients with ruptured aneurysms. Both the water load and mannitol increased postoperative

urine volumes and provided protection against postoperative oliguria. Mannitol was more efficient than the water load.

Although mannitol will increase the urinary output of the patient with an elective aneurysm or occlusive disease, there is relatively little danger of renal shutdown in these cases. It is in the patient with the ruptured or rupturing aneurysm, with the resulting shock, perirenal hematoma and massive blood transfusion that every effort should be made to prevent operative and postoperative oliguria.

DISCUSSION

Why should renal function be disturbed by aortic surgery? It has been suggested that occlusion of the infrarenal abdominal aorta either causes turbulence which affects the renal blood flow or else stimulates the sympathetic component of the autonomic nervous system and causes renal arteriolar spasm.[1, 2] Following occlusion of the infrarenal aorta of dogs, Gagnon *et al.*,[1] Nanson and Noble,[2] and Boba, Gainor and Powers, Jr.[3] all reported a marked diminution of renal blood flow and urine formation. Barry *et al.*[4] reported a similar occurrence in man. However, several other investigators (McGonigle, Seipel and Wylie,[5] Haimovici, Maier and Spiegler,[6] and Foster[7]) have found that temporary occlusion of the abdominal aorta does not cause any significant renal dysfunction. They have suggested that other factors, such as oligemic shock, calcium emboli or transfusion reactions, were more likely the cause of the oliguria.

Calcium and atheromatous emboli have been found at autopsy in the renal arteries of several of our patients and have been reported by Thurlbeck and Castleman.[8]

The incidence of acute renal shutdown following repair of a ruptured abdominal aortic aneurysm is high.[11] It is also variable from centre to centre, depending on the distance the patient is transported and the speed of surgery.[10] Although renal shutdown can occur following surgery of elective aneurysms and occlusive disease, it is much less common.[11, 12] The application of the occlusive clamp and the possibility of calcium emboli are common to both elective procedures and ruptured aneurysms; however, in the case of ruptured aneurysms, three other factors are present: oligemic shock, massive transfusion and flank hematomata. With oligemic shock there is a reduction in renal blood flow, a marked renal afferent arteriolar constriction, and reduced urine formation.[13] Following adequate blood replacement the urine output returns toward normal, provided that the arteriolar constriction has not been too severe or too prolonged.[14] However, adequate transfusion is often delayed. The massive transfusion of rapidly cross-matched blood may lead to mild transfusion reactions and the formation of nephrotoxic products requiring excretion. The flank hematomata may compress the renal veins and lead to further renal dysfunction.

Several measures have been advocated in attempts to reduce the incidence and severity of oliguria following this type of surgery. The injection of procaine or of large doses of saline into the periaortic tissues has been shown to increase renal blood flow.[2, 11] Ganglionic blocking agents administered systemically will also increase renal blood flow, but have the disadvantage of lowering the systemic blood pressure.[15] Gentleness in dissection, manipulation, and application of the clamp may reduce the incidence of atheromatous emboli. Adequate replacement of blood is essential. The slow release of the aortic clamp may avoid "declamping" shock.[16] The use of an osmotic diuretic during the period of surgery was first suggested by Barry, Cohen and LeBlanc[17] in 1961.

Mannitol is the reduced form of the six-carbon sugar mannose and possesses many properties which make it a safe and nearly ideal osmotic diuretic. It is inert and relatively non-toxic. It is freely filtered at the glomerulus and is not reabsorbed in the renal tubules. Within the tubule it is osmotically active and retains water. The retained water in the iso-osmotic proximal tubule dilutes the sodium and reduces its concentration and reabsorption at the sodium absorbing sites. The retained sodium and its accompanying anions in turn then behave as osmotic diuretic particles and add to the retained water which is passed on to the distal tubule. The total amounts of sodium, chloride and water presented to the distal tubule exceed its reabsorbing capacity and appear in large quantities in the urine. The urine which appears following such osmotic diuresis is similar in total concentration, pH, and individual ion concentration to that of the fluid in the proximal tubule.[18]

Boba and Landmesser[19] have suggested the following sequence to explain the renal shutdown which occurs following hemorrhage and trauma. The reduced renal blood flow and arteriolar constriction lead both to decreased glomerular filtration and to hypoxia of the tubular cells. The volume of the glomerular filtrate is so reduced that it is entirely reabsorbed in the proximal and distal tubules so that they have no fluid in their lumens. Following a return of normal blood volume, the hypoxic tubular cells swell and may completely occlude the lumen. The presence of the tight and non-expansile renal capsule aids in the production of a high intrarenal pressure. An osmotic diuretic, by increasing the amount of urine in the tubules (fluid is not compressible), would prevent the complete collapse of the tubular lumen and thus aid postoperative renal function. Mannitol is not toxic to the renal tubules as are the mercurials and other diuretics such as acetazolamide and chlorothiazide.[20]

Although it is not difficult to demonstrate an increased operative and postoperative urinary output in patients treated with mannitol as compared to those given an equal volume of 5% dextrose and water, it is difficult to prove conclusively that the

increased urine volume protects against renal shutdown. Beall and his associates,[10] in a study of 30 patients undergoing elective resection of abdominal aortic aneurysms, found that a water load (20 ml. per kg. over four hours preceding surgery) led to improved postoperative renal function and decreased renal vascular resistance, compared to a similar group without the water load. These workers could not demonstrate any further improvement with a mannitol infusion. Others[21, 22] have also expressed doubts as to the protective value of osmotic diuresis.

The results reported in this paper indicate the protective value of both a water load and a mannitol infusion in patients who were compared with the group who received no free fluid before or during operation, and in whom only blood loss was replaced. If an increased volume of fluid in the renal tubules protects against renal shutdown, then mannitol, which routinely produces a much higher operative and postoperative urine output, should be of greater value than either a water or saline load. Its use is particularly indicated in those patients whose renal function is already known to be impaired and in patients in whom suprarenal aortic occlusion or renal artery occlusion may be required. In the patient with a ruptured aneurysm, the flank hematoma, the shock, the massive transfusion required, and the occasional necessity to clamp the aorta above the renal arteries, all suggest the need for maximal renal protection. Several patients with ruptured aortic aneurysms who arrived in the Emergency Department in a state of anuria responded dramatically to immediate mannitol infusion.

We believe that an osmotic diuretic should be available and should be administered, along with blood replacement, during the transportation of patients with ruptured or rupturing aneurysms of the abdominal aorta from referring hospitals to vascular centres. It should be administered before and during the period of aortic occlusion necessary in the surgical repair of such aneurysms. Its use also should be considered in those elective procedures in which cross-clamping of the abdominal aorta is required if there is any known renal disease, or if hypotension occurs during the procedure.

SUMMARY

A review of 28 patients who had operations in 1960-61 in which the infrarenal aorta was temporarily occluded (aneurysms operated upon electively, ruptured abdominal aortic aneurysms, and aorto-iliac occlusive disease) showed that five died of acute renal shutdown and that the postoperative urinary output was low. The 27 subsequent patients were divided into two groups, one receiving a water load and one receiving an osmotic diuretic, mannitol. No case of renal failure occurred in either group. The urinary output of the patients receiving mannitol was much greater than that of the patients who received a water load, despite the fact that the mannitol-treated group included many more patients with ruptured aneurysms. The use of mannitol is advocated for the patient with a ruptured abdominal aneurysm during the emergency treatment, transportation and surgical repair.

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REFERENCES

1. GAGNON, J. A. *et al.*: *Surgery*, 47: 240, 1960.
2. NANSON, E. M. AND NOBLE, J. G.: *Ibid.*, 46: 388, 1959.
3. BOBA, A., GAINOR, J. AND POWERS, S. R., JR.: *Ibid.*, 52: 188, 1962.
4. BARRY, K. G. *et al.*: *Clin. Res.*, 8: 364, 1960.
5. MCGONIGLE, D. J., SEIPEL, R. S. AND WYLIE, E. J.: *Surgery*, 49: 235, 1961.
6. HAIMOVICI, H., MAIER, N. AND SPIEGLER, E.: *J. Cardiov. Surg.*, 2: 206, 1961.
7. FOSTER, J. H.: In discussion: *Arch. Surg. (Chicago)*, 86: 48, 1963.
8. THURLBECK, W. M. AND CASTLEMAN, B.: *New Eng. J. Med.*, 257: 442, 1957.
9. LUKE, J. C.: In discussion: *Arch. Surg. (Chicago)*, 86: 42, 1963.
10. BEALL, A. C., JR. *et al.*: *Ibid.*, 86: 34, 1963.
11. POWERS, S. R., JR., BOBA, A. AND STEIN, A.: *Surgery*, 42: 156, 1957.
12. SHERANIAN, L. O., EDWARDS, J. E. AND KIRKLIN, J. W.: *Surg. Gynec. Obstet.*, 109: 309, 1959.
13. PHILLIPS, R. A. *et al.*: *Amer. J. Physiol.*, 145: 314, 1946.
14. BLOOM, W. L.: *A.M.A. Arch. Surg.*, 63: 739, 1951.
15. WHITLEY, J. E. *et al.*: *Surgery*, 50: 673, 1961.
16. STRANDNESS, D. E., JR., PARRISH, D. G. AND BELL, J. W.: *Ibid.*, 50: 488, 1961.
17. BARRY, K. G., COHEN, A. AND LEBLANC, P.: *Ibid.*, 50: 335, 1961.
18. BERNSTEIN, L. M. AND GROSSMAN, A.: *J. Lab. Clin. Med.*, 59: 309, 1962.
19. BOBA, A. AND LANDMESSER, C. M.: *Anesthesiology*, 22: 781, 1961.
20. RABELO, A. *et al.*: *Surg. Gynec. Obstet.*, 115: 657, 1962.
21. BERRY, R.: In discussion: *Surgery*, 52: 193, 1962.
22. SHAW, R. S.: In discussion: *Ibid.*, 52: 193, 1962.

PAGES OUT OF THE PAST: FROM THE JOURNAL OF FIFTY YEARS AGO

C.M.A. COMMITTEE ON MEDICAL INSPECTION OF SCHOOLS

(Continued from page 701)

Now, if the direction and control of medical inspection is to lie with the educational authority each province of the Dominion will have its own system. The general features may be the same, but the details are certain to vary, as they do now, and the results could not in any sense be looked upon as national.

It seems eminently desirable that a uniform system of medical inspection should be in use throughout the Dominion. There seems to be little prospect that our present system of education will be changed from a provincial to a federal system. But the circumstances which stand in the way of a federal ministry of education need not obstruct the establishment of a federal ministry of public health. And it is only by the creation of such a ministry that a system of medical inspection, uniform in method and scope and truly national in extent, can be established in Canada.

Such a public health service, taking cognizance of all matters pertaining to the national health, correlating the various branches of public health, the immigration and quarantine stations, the sanitation of factories and public buildings, the army medical service with its recruiting stations and camps, the control of infectious diseases, and the various agencies to secure the public against the adulteration and contamination of food, would seem to be also the proper authority to direct and control the medical inspection of schools.—*Canad. Med. Ass. J.*, 3: 729, 1913.