Effect of Mannitol on Renal Function During Open-Heart Surgery *

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MANNITOL has been shown to increase the glomerular filtration rate and the renal plasma flow without significantly increasing the blood volume [1] and has been successfully used in preventing acute renal failure in experiments designed to produce this complication.[6] Adequate hydration during anesthesia and surgical manipulation without the addition of mannitol has been shown to decrease the incidence of acute renal failure following experimental surgical manipulation in dogs. Mannitol has the advantage of maintaining urine flow in spite of the antidiuresis which invariably accompanies anesthesia, surgical manipulation and open-heart surgery. This facilitates maintenance of the fluid balance that otherwise might be difficult and removes the element of danger which accompanies hydration with other fluids in an antidiuretic patient. Continuous assessment of the fluid balance is, of course, mandatory to avoid over-hydration and dilutional hyponatremia.

Studies over a 1-year period of renal function during mannitol administration in open-heart operations are presented in detail for 18 patients. Results indicate that mannitol infusion initiated shortly after the induction of anesthesia and continued throughout the postoperative period is a practical, effective means of increasing glomerular filtration rate and maintaining urine flow, while also allowing maintenance of the fluid and electrolyte balance. During this year, no cases of acute renal failure were observed.

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Methods

Fifty-four consecutive patients having elective open-heart surgery, from May, 1962, to May, 1963, in whom the period of cardiopulmonary bypass was expected to exceed one hour, were given mannitol. Of this group, 18 patients, selected at random, were studied intensively and are the subjects of this report.

The time during operation was divided into four experimental periods: Period I (control), from the induction of anesthesia to the initiation of the mannitol infusion; Period II (pre-bypass), from the beginning of the mannitol infusion to the establishment of the cardiopulmonary bypass; Period III (bypass); and Period IV (post-bypass), from the end of cardiopulmonary bypass until the application of dressings. Urine was collected by an indwelling catheter draining into a graduated cylinder; urine volume and specific gravity were measured every 30 minutes throughout the surgical procedure. Urine samples were collected

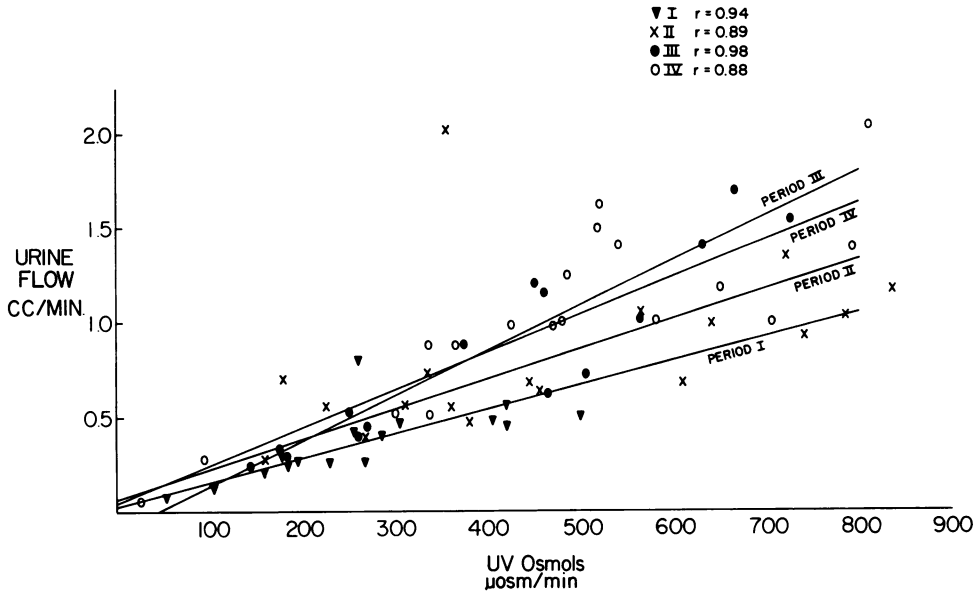

FIG. 1. The relationship of solute output (UV osmols) to urine flow during open-heart surgery.

separately for each of the experimental periods. Blood samples were collected at the end of each experimental period.

The following laboratory determinations were conducted for each experimental period: serum osmolality, sodium, potassium, chloride and creatinine, and blood urea nitrogen; urine osmolality, sodium, potassium, chloride and creatinine. The following standard calculations were made for each experimental period: creatinine clearance, urinary excretion of sodium per minute (UV sodium), UV potassium, and UV chloride. Also calculated were UV osmols, sodium clearance, per cent of filtered sodium excreted, and clearance of free water. For each patient plasma hemoglobin was determined preoperatively and at the end of the procedure.

A 10 per cent solution of mannitol in 0.54 per cent saline was prepared as follows: 200 cc. of 25 per cent mannitol in water (four ampules) were added to 300 cc. of 0.9 per cent saline. The mannitol was administered by continuous intravenous infusion in amounts based on the patient's urine output. In the first hour, because the state of hydration and glomerular filtration rate varied from patient to patient, the amount of mannitol given was limited to 100 cc. of the 10 per cent solution. Arbitrarily an attempt was made to maintain a urine output of about 30 cc./m.^{2} of body surface/hr., and mannitol was administered in amounts necessary to maintain as closely as possible this rate during a given period. The insensible loss was considered to be 20 cc./m.^{2} of body surface/hr. and additional fluid was administered to cover this loss. The mannitol infusion rate was increased when the urine output dropped below the calculated desired level and decreased when the urine output was large enough to cause a negative noncolloid fluid balance, in which case the calculated fluid balance was maintained by administering a solution of 2.5 per cent dextrose and 0.2 per cent saline. When the desired urine output was maintained easily with a small volume of a 10 per cent solution of mannitol, a 5 per cent solution was substituted. Occasionally, where there was a danger of overload of the circulation by a large positive noncolloid fluid balance, smaller vol-

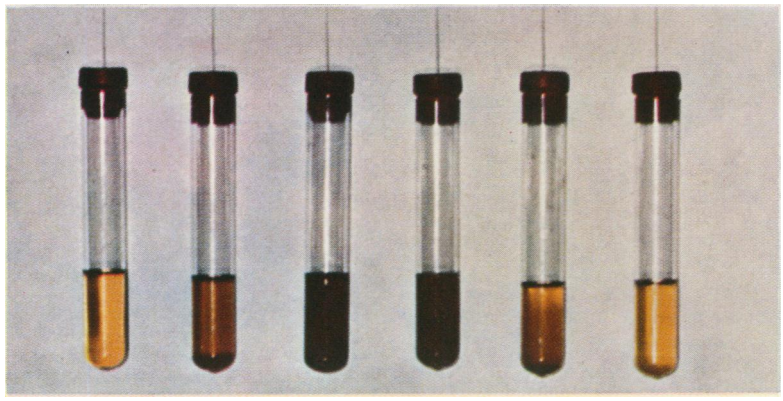

FIG. 2. Hemoglobinuria with prolonged cardiopulmonary bypass (3 hrs. 12 mins.) in a patient receiving prophylactic mannitol. Aliquots of urine taken at intervals. From left to right: Specimen 1, before bypass; specimens 2 and 3, on bypass for 2 and 3 hours, respectively; specimens 4, 5 and 6, off bypass for 2, 4 and 6 hours, respectively. Mannitol was administered throughout the operation and during the postoperative period to maintain an active flow of urine. The intense hemoglobinuria which developed during cardiopulmonary bypass rapidly cleared after bypass was discontinued.

umes of a 25 per cent solution were administered.

Postoperatively, mannitol infusions were continued until the urine output, venous pressure, arterial pressure and pH were stable. In patients with gross hemoglobinuria the urine output was kept at 30 to 50 cc./m.^{2} of body surface/hr. until the urine samples were visibly free of discoloration (Fig. 2). Mannitol was usually discontinued 24 to 36 hours postoperatively, though in one case it was continued for 9 days (patient M. W.).

The postoperative follow-up study included daily determinations of urine output and BUN. In patients with prolonged hypotension, acidosis, or very low or very high outputs of urine, blood and urinary electrolytes and osmolalities were determined at frequent intervals. The lowest postoperative urine volume with the day of its occurrence and the highest BUN with the day of its occurrence were recorded.

Results

The urine output, the mannitol dosage and the creatinine clearance of each of the four experimental periods are presented in Table 1.

In Period II, following the infusion of mannitol, 10 of the 14 patients in whom comparison with Period I was possible showed an increase in creatinine clearance of 4 to 112 per cent; 16 of the 18 patients also showed an increase in urine flow. In Period III (bypass), despite the infusion of mannitol, 17 of 18 patients showed a decrease in creatinine clearance from Period II of 5 to 87 per cent; 12 of these also showed a decrease in urine flow of 3 to 62 per cent, while six showed an increase of 13 to 648 per cent. It is of interest that these six patients with increased urine flow in this period (bypass) had a decreased creatinine clearance, and further, that four of these six received less mannitol per hour in Period III than in Period II.

Of the 12 out of 18 patients having reduced urine flows in Period III eight had flows in this period (bypass) that were still larger than in Period I. Also ten of the 12 received less mannitol per hour in Period III than in the preceding period. In five of the six having larger urine flows

TABLE 1. *The Relationship of Urine Flow to Glomerular Filtration Rate During Mannitol Infusion and Open-Heart Surgery*

Patient	Length of Cardiopulmonary Bypass (min.)	Creatinine Clearance (cc./min.) Period				Urine Flow (cc./min.) Period				Mannitol Infused (Gm./hr.) Period			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
Increased Urine Flow During Bypass													
A. B.	163	76.0	91.00	49.00	45.0	0.470	1.060	1.200	1.500	—	12.70	6.110	34.300
M. W.	423	59.0	57.00	30.00	10.0	0.300	0.710	1.160	0.280	—	14.30	13.000	5.830
P. M.	84	64.0	128.00	59.00	55.0	0.430	0.660	4.940	1.180	—	4.11	3.000	0.918
G. N.	386	80.0	86.00	25.00	32.0	0.250	0.550	0.900	1.400	—	5.13	8.720	4.510
V. A.	312	—	92.00	82.00	70.0	—	0.990	1.540	1.020	—	7.04	4.480	1.280
H. H.	266	34.1	74.00	25.00	31.0	0.170	0.740	1.400	0.930	—	5.40	6.290	0
Decreased Urine Flow During Bypass													
G. C.	124	114.0	119.00	58.00	77.0	0.500	0.930	0.740	1.000	—	13.20	9.200	12.800
P. M.	58	40.0	68.00	26.00	53.0	0.270	0.570	0.380	1.000	—	8.80	0.345	12.400
E. E.	130	—	46.00	18.00	30.0	0.270	0.400	0.240	0.530	—	2.89	4.290	2.900
M. L.	134	61.0	53.00	55.00	43.0	0.420	2.300	1.700	1.600	—	0.27	4.440	1.800
M. P.	57	31.0	69.00	23.00	42.0	0.200	0.540	0.330	0.890	—	4.97	4.500	2.220
A. D.	251	90.0	51.00	16.00	1.1	0.270	0.480	0.290	0.040	—	3.75	3.990	2.140
R. D.	193	73.0	119.00	33.00	24.0	0.800	1.370	0.510	0.860	—	4.87	6.140	3.370
D. H.	197	108.0	215.00	68.00	104.0	0.440	1.050	1.020	1.400	—	9.18	5.940	4.180
G. Q.	94	130.0	84.00	80.00	70.0	0.550	0.680	0.640	0.500	—	2.56	10.260	0.500
L. D.	290	80.0	136.00	18.10	29.0	0.400	0.610	0.230	1.250	—	7.33	7.550	0
W. C.	61	—	82.30	46.40	122.0	0.083	0.290	0.210	1.000	—	6.67	10.750	1.560
T. F.	186	—	126.52	21.80	61.0	—	1.173	0.454	2.123	—	5.69	8.760	6.640

in Period III the flows were larger than in Period I (control).

In Period IV (after cardiopulmonary bypass) 10 of the 18 patients had an increase in creatinine clearance values from Period III; nine of these ten had concomitant increase in urine flow in comparable periods, though only two of the ten received an increase in grams of mannitol. Eight patients had a decrease in creatinine clearance in Period IV compared with Period III; of these, six had a decrease in urine flow. The only one of eight to receive more mannitol in Period IV had an increase in urine flow with a decrease in creatinine clearance.

The serum electrolytes, blood urea nitrogen and serum osmolality for each of the four periods are recorded in Table 2. Serum sodium values remained essentially constant throughout the operation whereas there was greater variation in the serum potassium values. The serum chloride concentration remained quite stable and in most cases paralleled changes in serum sodium in magnitude and direction.

The blood urea nitrogen values showed a slight progressive rise throughout the operation; however, the mean BUN value for Period IV (18.3 mg./100 ml.) was only 2.8 mg./100 ml greater than the mean BUN value (15.5 mg./100 ml.) for Period I. The lowest BUN recorded during the operation was 9 mg./100 ml., the highest, 26 mg./100 ml.

Serum osmolalities remained essentially constant throughout the four periods although there was a slight progressive rise in mean values in each period.

The data on solute excretion are presented in Table 3. There is considerable individual variation in UV sodium and UV potassium values; however, the mean values for UV sodium for Period I through IV are 25, 20, 30 and 24 μEq./min., respectively. One must note that only seven patients actually showed an increase in the UV sodium value during bypass (Period III) as compared to the pre-bypass period (II). Of these seven, six were those previously described as having an increased urine flow in spite of a reduced glomerular filtration rate during bypass (Period III). Ten of 17 patients showed a reduction in UV sodium in Period III as compared to Period II, and all 10 had a reduced creatinine clearance for comparable periods.

There was considerable variation in the individual UV chloride values, but the variation was parallel in direction and magnitude to the UV sodium values.

The excretion of total solute per minute (UV osmols) varied considerably from patient to patient and period to period. However, in any given period, there was, as would be expected, a close correlation between the solute output per minute and the urine flow. In Figure 1 data are shown with a mean regression line plotted for each period. Note that the period prior to the infusion of mannitol (Period I) was associated with a generally lower solute and urine output and the two later periods (Periods II and III) were associated with considerable variation in the solute output. Following the bypass period the solute and urine output values tended to be higher.

Osmolal clearances were varied. In all the 14 patients who could be compared the osmolal clearance increased in Period II from the preceding control period. In 10 of 18 patients the osmolal clearance decreased from Period II to Period III and in eight it increased.

Table 4 presents the creatinine clearance, sodium clearance, percentage of filtered sodium excreted and clearance of free water. In only four of the 14 patients was the sodium clearance higher in Period II than in Period I, and in only two of these four was the per cent filtered sodium excreted higher in Period II. Comparing the per cent of filtered sodium excreted in the bypass period (III) with that excreted in the control period, five values had in-

TABLE 2. *Serum Electrolytes, Osmolalities, and Blood Urea Nitrogens during Mannitol Infusion and Open-Heart Surgery*

	Serum Sodium (mEq./L.) Period				Serum Potassium (mEq./L.) Period				Serum Chloride (mEq./L.) Period				BUN (mg./100 ml.) Period				Serum Osmolality (mOsmols/Kg.) Period			
Patient	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
									Increased Urine Flow During Bypass											
A. B.	136	134	136	137	H	H	H	H	98	100	100	103	16	18	16	19	282	289	293	297
M. W.	140	137	136	141	H	H	H	H	104	105	104	99	14	15	16	21	283	287	291	304
P. M.	136	135	133	135	4.5	3.6	3.9	3.0	104	106	104	104	16	16	17	18	282	287	290	292
G. N.	137	138	132	142	4.6	5.7	3.0	2.5	101	102	100	96	25	22	25	25	288	292	296	314
V. A.	137	137	133	140	4.4	3.8	3.0	2.7	106	108	108	106	11	9	12	16	281	285	297	305
H. H.	145	143	141	141	4.4	3.6	H	H	108	107	107	105	17	17	16	17	287	297	303	295
									Decreased Urine Flow During Bypass											
G. C.	138	135	136	136	4.4	3.9	3.4	3.7	106	105	105	105	11	10	11	11	279	281	287	286
P. M.	141	139	140	137	3.7	3.1	2.6	3.2	102	103	102	99	16	16	14	14	285	282	284	302
E. E.	—	141	139	139	—	4.5	3.3	4.0	—	105	107	108	—	26	23	25	—	287	291	295
M. L.	136	138	136	134	H	3.2	3.1	3.0	104	104	104	103	18	19	19	20	278	279	287	288
M. P.	138	136	137	135	4.6	3.9	3.3	4.2	104	100	102	106	16	17	19	QNS	280	290	294	296
A. D.	136	132	140	144	5.5	4.8	4.0	3.8	98	96	100	95	19	19	19	21	281	281	291	321
R. D.	134	140	140	138	H	2.8	H	H	93	100	100	104	10	14	14	16	280	285	290	295
D. H.	142	139	141	141	4.2	4.0	3.0	3.6	104	104	105	104	15	16	18	20	279	284	290	290
G. Q.	—	123	136	124	—	3.2	3.0	3.0	—	94	101	90	—	12	14	14	—	284	292	287
L. D.	135	136	132	163	4.4	4.2	H	H	101	100	102	98	17	17	19	23	285	293	310	348
W. C.	138	133	133	135	4.0	4.6	3.8	3.3	97	100	98	103	15	16	16	17	285	283	287	291
T. F.	137	137	133	136	3.5	2.7	3.6	3.8	101	103	101	101	12	12	12	15	—	284	294	300

H = Hemolysis.

TABLE 3. *Solute Excretion During Mannitol Infusion and Open-Heart Surgery*

Patient	UV Sodium (μEq./min.) Period				UV Potassium (μEq./min.) Period				UV Chloride (μEq./min.) Period				UV Osmols (μosmols/min.) Period			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
								Increased Urine Flow During Bypass								
A. B.	2.35	1.06	1.20	16.40	30	51	41	64	2.0	4.0	1.0	3.00	304	566	449	515.0
M. W.	0.90	0.71	66.10	0.28	11	77	50	8	4.0	4.0	75.0	0.50	179	407	457	93.8
P. M.	73.00	27.00	61.00	103.00	21	92	84	35	86.0	59.0	553.0	21.24	405	611	1,768	649.0
G. N.	0.25	0.55	52.20	21.00	38	30	40	42	9.0	5.0	55.0	17.00	184	360	375	538.0
V. A.	—	2.97	55.40	255.00	—	87	55	43	—	14.0	97.0	24.00	—	638	725	477.0
H. H.	9.30	0.74	22.40	3.72	14	15	31	35	21.0	10.0	20.0	5.00	105	338	630	420.0
								Decreased Urine Flow During Bypass								
G. C.	61.00	106.00	28.10	52.00	27	47	36	64	70.0	131.0	10.0	35.00	500	742	505	705.0
P. M.	33.40	18.10	10.30	32.00	21	53	37	74	37.0	18.0	4.0	12.00	230	438	257	578.0
E. E.	0.27	0.40	0.24	0.53	26	54	22	28	0.5	0.8	0.5	0.50	268	259	141	299.0
M. L.	31.90	27.40	142.00	106.00	16	55	44	45	32.0	30.0	153.0	119.00	256	353	663	516.0
M. P.	14.20	1.62	—	10.70	15	28	—	30	31.0	99.0	—	4.00	160	313	175	366.0
A. D.	14.90	4.80	0.87	0.04	13	42	13	1	17.0	13.0	2.0	0.04	195	383	183	21.2
R. D.	32.00	5.50	2.00	3.40	22	55	18	16	3.0	5.0	4.0	0.80	260	721	249	337.0
D. H.	73.00	35.00	29.60	14.00	40	210	49	59	99.0	74.0	22.0	7.00	427	786	565	791.0
G. Q.	21.50	26.50	14.10	5.00	21	26	40	20	13.0	16.0	14.0	1.50	419	445	462	337.0
L. D.	23.20	16.50	5.06	26.30	23	56	17	54	16.0	21.0	7.0	4.00	282	452	145	482.0
W. C.	2.82	8.99	5.67	6.00	5	23	21	54	6.0	11.0	5.0	6.00	55	160	106	468.0
T. F.	—	78.59	14.98	10.64	—	121	34	57	—	184.0	29.0	8.00	—	835	274	809.0

TABLE 4. *Creatinine Clearance, Sodium Clearance, Per cent of Filtered Sodium Excreted and Clearance of Free Water During Mannitol Infusion and Open-Heart Surgery*

	Creatinine Clearance (cc./min.) Period				Sodium Clearance (cc./min.) Period				% Filtered Sodium Excreted Period				Clearance of Free Water (cc./min.) Period			
Patient	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
								Increased Urine Flow During Bypass								
A. B.	76.0	91.0	49.0	45.0	0.017	0.008	0.009	0.120	0.020	0.008	0.020	0.300	−0.610	−0.890	−0.330	−0.245
M. W.	59.0	57.0	30.0	10.0	0.006	0.005	0.490	0.002	0.010	0.010	1.600	0.020	−0.330	−0.710	−0.410	−0.030
P. M.	64.0	128.0	59.0	55.0	0.540	0.200	0.460	0.770	0.800	0.200	0.800	1.400	−1.007	−1.470	−1.150	−1.040
G. N.	80.0	86.0	25.0	32.0	0.002	0.004	0.390	0.150	0.002	0.004	1.600	0.460	−0.390	−0.680	−0.370	−0.310
V. A.	—	92.0	82.0	70.0	—	0.020	0.420	0.180	—	0.020	0.500	0.200	—	−1.250	−0.900	−0.540
H. H.	34.0	74.0	25.0	31.0	0.060	0.006	0.160	0.030	0.180	0.006	0.600	0.080	−0.199	−0.400	−0.680	−0.490
								Decreased Urine Flow During Bypass								
G. C.	114.0	119.0	58.0	77.0	0.442	0.785	0.206	0.382	0.400	0.700	0.400	0.500	−1.300	−1.700	−1.020	−1.500
P. M.	40.0	68.0	26.0	53.0	0.240	0.130	0.070	0.730	0.600	0.200	0.300	0.400	−0.542	−0.987	−0.520	−0.910
E. E.	—	46.0	18.0	30.0	—	0.003	0.002	0.004	—	0.010	0.010	0.010	—	−0.503	−0.245	−0.480
M. L.	61.0	53.0	55.0	43.0	0.235	0.200	1.100	0.800	0.400	0.400	2.000	1.800	−0.500	−1.010	−0.610	−0.230
M. P.	31.0	69.0	23.0	42.0	0.102	0.012	—	0.080	0.300	0.010	—	0.010	−0.370	−0.540	—	−0.340
A. D.	90.0	51.0	16.0	1.1	0.110	0.040	0.006	0.001	0.100	0.070	0.030	0.100	−0.420	−0.880	−0.340	−0.030
R. D.	73.0	119.0	33.0	24.0	0.024	0.040	0.014	0.025	0.130	0.030	0.040	0.100	−0.128	−1.150	−0.350	−0.280
D. H.	108.0	215.0	68.0	104.0	0.510	0.250	0.210	0.100	0.500	0.100	0.300	0.010	−1.090	−1.720	−0.930	−1.330
G. Q.	130.0	84.0	80.0	70.0	—	0.220	0.100	0.040	—	0.200	0.140	0.070	—	−0.880	−0.940	−0.680
L. D.	80.0	136.0	18.1	29.0	0.170	0.120	0.040	0.160	0.200	0.090	0.210	0.550	−0.590	−0.930	−0.230	−0.136
W. C.	—	82.3	46.4	122.0	0.020	0.070	0.040	0.040	0.370	0.080	0.090	0.030	−0.110	−0.270	−0.160	−0.610
T. F.	—	126.0	21.8	61.0	—	0.570	0.110	0.080	—	0.400	0.180	0.120	—	−1.770	−0.470	−0.570

creased, five had decreased and three were essentially constant. The lowest value for filtered sodium excreted was 0.002 per cent, the highest value, 2.0 per cent.

In all recorded cases except one (Patient M. L.) there was a negative value for free water clearance. This single positive value was recorded in Period II, at a creatinine clearance of 53 cc./min., a serum osmolality of 279 mOsm./L. and a urine osmolality of 155 mOsm./L.

Sodium clearance and the per cent of filtered sodium excreted was higher in those six patients having a higher urine flow with reduced glomerular filtration rate in the bypass period than before bypass. Five of these six patients had a change in the negative clearance of free water values toward the zero value, although all still retained a negative value.

Discussion

The intravenous infusion of mannitol is a safe, practical method for improving renal function during open-heart surgery. Hemolysis, acidosis, reduction in renal plasma flow and in glomerular filtration rate, and antidiuresis are predisposing factors in the development of acute renal failure, inevitably occurring during anesthesia and open-heart surgery. Additional hazards are hypotension, dehydration and transfusion reaction which can further damage the susceptible kidney. Experiments have shown that mannitol and adequate hydration or both can prevent renal failure in the presence of one or more of the above predisposing factors.[5] This drug has long been known to be nontoxic, inert and extremely potent as an osmotic diuretic. Recently, evidence has been presented that, in addition to the osmotic effect inhibiting the reabsorption of water from the renal tubules, other mechanisms are operative: an increased plasma volume as evidenced by a decreased blood hematocrit, a decreased renal vascular resistance and increased renal blood flow.[2, 4]

In animal or man with normal kidneys, mannitol induces a brisk diuresis associated with increased excretion of essentially all normal constituents of urine such as sodium, potassium and chloride. If used indiscriminantly it can cause a severe electrolyte derangement. By maintaining the proper salt and water balance this can be prevented and thus, as this study demonstrates, mannitol can be infused for extended periods in spite of the variation in renal function induced by anesthesia and cardiopulmonary bypass.

A consistent effect of cardiopulmonary bypass on the kidneys is reduction of the glomerular filtration rate. This has been demonstrated by Senning *et al.*[7] and was seen in 17 of the 18 patients studied in our series. Such a marked reduction is usually accompanied by a marked reduction in the urine flow and excretion of sodium. The decrease in urine flow may be offset by the osmotic effect of any filterable but nonreabsorbable solute such as mannitol. Furthermore, mannitol infusion was associated with an increase in the glomerular filtration rate in a majority of the patients studied (Period II). The wide variation between the amounts of mannitol solution needed and the urine flow is undoubtedly a reflection of the variation in the glomerular filtration rate and clinical state from patient to patient. There is, as might be expected, a good correlation between solute and urine output (Fig. 1). This suggests that a constant monitoring of the urine flow is an adequate means of judging the amount of mannitol to be infused. During Period I (before mannitol) the total solute output was low and the urine volume correspondingly low. In Period II (during mannitol infusion) the glomerular filtration rate and the total solute output increased, in most cases inducing a rise in urine volume. In Period IV, the recovery period following bypass and continuous loading with mannitol, the solute output was high and the urine volume proportionately high (high

glomerular filtration rate and mannitol). In Period III, during cardiopulmonary bypass, the marked reduction in glomerular filtration rate prevented a large diuresis except in the six cases. It is fair to assume, however, that the urine flow during this period was in excess of that which would have been present if mannitol had not been given; in several cases the urine flow did exceed that seen in the Period I (control). The increase in urine flow and glomerular filtration rate is valuable in clearing the plasma of free hemoglobin rapidly and preventing the formation of acid hematin casts in the collecting tubules.

There were six patients with a reduction in glomerular filtration rate associated with an increase in urine flow and an increase in UV sodium during bypass (Period III). This finding of a reduced glomerular filtration rate with an increase in UV sodium is similar to the observation of Levinsky *et al.*[3] in dogs where, under conditions of salt loading and an acute reduction of the glomerular filtration rate, the per cent of filtered sodium excreted was far in excess of the values seen in control animals. It is interesting that this phenomenon, which strongly indicates a mechanism other than glomerular filtration rate and aldosterone for control of sodium excretion, is observed in humans.

Summary

The intravenous use of a 10 per cent solution of mannitol in cardiac operations requiring cardiopulmonary bypass in excess of 1 hour is reported.

Extensive physiologic data on renal function and blood chemistries are presented for a group of 18 patients.

Mannitol increased the glomerular filtration rate and urine flow in most patients before and after cardiopulmonary bypass. During bypass there was a reduction in glomerular filtration rate. In 12 of 18 patients this was associated with a reduction in sodium excretion and a reduction in urine flow. In six of 18 patients, despite a reduction in glomerular filtration rate, there was an increase in both sodium excretion and urine flow. This response could not be attributed to mannitol infusion.

No cases of acute renal failure were seen during the 1-year period of this study.

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