RENAL FUNCTION DURING ANESTHESIA FOR CARDIOVASCULAR SURGERY

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MORE than half a century ago it was found that ether anesthesia in man produced oliguria with depression in sodium and nitrogen excretion.[19] Since then, both clinical and laboratory observations on the effects of general anesthetic agents on kidney function have indicated only small variation in this theme of renal supression. In recent years, however, techniques and concepts in anesthesiology have altered as a result of the introduction of the muscle relaxants. These drugs have made possible the achievement of a quiet operative field with lighter planes of anesthesia. Another innovation leading to the use of reduced quantities of anesthetic agents has been the concept of "balanced anesthesia" in which multiple anesthetic agents are employed in the same patient, but each in small quantities. A clinical appraisal of the effects on renal function of these newer anesthetic techniques which we have employed during cardiovascular operations would appear valuable. In this study, renal hemodynamics, together with water and electrolyte excretion, were determined before and after induction of anesthesia, but prior to the commencement of major cardiovascular operations.

METHODS

The subjects of this study were 24 male and female patients, ranging in age from 11 to 66 years. Nine of these patients subsequently underwent open cardiac surgery for repair of congenital or acquired intracardiac defects and 15 underwent resection of thoracic aneurysms with graft replacement. Each patient was studied during two periods: (1) a control period prior to induction of anesthesia, but 30 to 45 minutes following administration of premedicating drugs, and (2) an anesthesia period which began approximately 30 minutes after induction of anesthesia. During the control period, measurements were made over three separate 10-minute intervals and during the anesthesia period measurements were made over two 10-minute intervals. Measurements included mean blood pressure, glomerular filtration rate, renal blood flow, and excretion of water and electrolytes. Mean blood pressure was calculated from the auscultatory determination by adding one-third the pulse pressure to the diastolic pressure. Inulin clearance was used to determine glomerular filtration rate and para-aminohippurate to obtain renal plasma flow. Renal blood flow was derived from renal plasma flow with the hematocrit. Plasma and urine determination of sodium and potassium were made using a Beckman Flame Photometer. Methods and techniques have been described previously.[15]

Premedication for all patients consisted of the following drugs and doses for the 150 pound patient: promethazine 25 mg., meperidine 50 mg., and scopolomine 0.4 mg. Premedication for individual patients was adjusted for body size and decreased in those debilitated by their disease. By the design of this study the effects of these drugs were present during both observation periods. In nineteen of the 24 patients anesthesia was induced with 100 to 200 mg. of 2 per cent thiopental intravenously followed by 50 per cent cyclopropane in oxygen. In five anesthesia was induced with 50 per cent cyclopropane. When consciousness was lost, 0.1 per cent succinylcholine was administered by intravenous drip. When respiration became inadequate the patient's lungs were manually ventilated with cyclopropane in oxygen and tracheal intubation accomplished when apnea developed. The time required from induction to tracheal intubation was usually 5 to 10 minutes. Following tracheal intubation, cyclopropane was discontinued, the rebreathing bag was emptied, and ether added to the system with an oxygen flow rate of 1 to 2 liters per

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TABLE 1

The Effect of Anesthesia on Renal Hemodynamics and Water and Electrolyte Excretion

Patient	Age	Sex	Mean Blood Pressure (mm. Hg)			Glomerular Filtration Rate (ml./minute)			Renal Blood Flow (ml./minute)			Hematocrit			Urine Volume (ml./minute)			Na Plasma (mEq./l.)			K Plasma (mEq./l.)			Na Urine (mEq./minute)			K Urine (mEq./minute)		
			C	An	%	C	An	%	C	An	%	C	An	%	C	An	%	C	An	%	C	An	%	C	An	%	C	An	%
1	61	F	99	93	94	86	78	91	868	748	86	40	40	100	0.4	0.5	125	149	148	99	5.9	5.9	100	83	85	102	42	40	95
2	42	M	99	72	73	100	99	99	1,459	1,378	95	51	51	100	0.4	0.4	100	134	139	104	4.4	4.4	100	135	134	99	43	50	116
3	42	F	70	70	100	88	59	67	772	380	49	46	46	100	0.5	0.4	80	144	152	106	3.0	3.0	100	93	51	55	83	34	41
4	41	M	73	70	96	101	81	80	1,065	1,131	106	46	45	98	0.4	0.4	100	150	150	100	3.6	3.2	89	54	47	87	27	37	137
5	58	M	77	77	100	82	102	125	1,006	1,385	138	47	47	100	0.5	0.5	100	151	151	100	4.1	4.1	100	94	101	107	34	72	212
6	21	F	103	97	94	101	89	88	1,411	1,215	86	45	45	100	1.0	0.9	90	—	—	—	—	—	—	—	—	—	—	—	—
7	53	M	132	127	96	97	81	84	802	846	105	43	43	100	2.0	1.4	70	142	143	101	5.1	4.7	92	340	265	78	102	91	89
8	54	M	120	117	98	109	157	144	993	1,256	126	32	32	100	1.4	2.7	193	141	134	95	3.7	3.8	103	—	—	—	50	95	190
9	64	M	82	97	118	32	38	119	485	579	119	38	38	100	0.6	0.6	100	130	130	100	5.0	4.7	94	121	75	62	22	22	100
10	46	M	113	123	109	88	81	92	1,198	1,037	87	51	51	100	0.7	0.4	57	134	127	95	4.1	3.6	88	91	91	100	66	56	85
11	66	M	120	120	100	70	90	129	834	876	105	42	42	100	1.4	2.0	143	136	131	96	6.5	5.4	83	264	144	55	92	88	96
12	51	M	140	147	105	113	71	63	883	640	72	41	40	98	1.4	1.5	107	150	154	103	3.6	4.5	125	148	136	92	33	30	91
13	28	F	113	110	97	67	92	137	556	749	135	43	43	100	0.7	0.2	29	139	133	96	3.7	4.0	108	156	125	80	27	19	70
14	10	F	97	97	100	45	41	91	510	373	73	48	48	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
15	67	F	84	67	80	61	46	76	661	507	77	44	42	96	0.3	0.1	33	148	148	100	3.9	3.9	100	119	148	124	28	32	114
16	57	M	97	87	90	65	66	102	951	770	81	47	47	100	1.0	1.4	140	149	148	99	4.1	4.1	100	99	108	109	30	38	127
17	55	M	95	82	86	75	72	96	568	543	96	47	47	100	0.9	0.1	11	—	—	—	—	—	—	—	—	—	—	—	—
18	61	F	127	118	93	30	40	133	255	365	143	45	45	100	0.7	0.4	57	140	134	96	3.7	3.9	105	138	67	49	19	23	121
19	47	M	163	95	58	134	114	85	1,698	1,793	106	49	44	90	1.3	1.3	100	133	130	98	6.5	6.3	97	76	42	55	34	25	74
20	27	F	75	57	76	59	44	75	517	560	108	46	43	94	0.3	0.2	67	122	123	101	3.8	4.3	113	80	40	50	15	11	73
21	42	F	93	94	101	77	87	113	873	698	80	45	45	100	0.6	0.4	67	139	136	98	4.4	3.7	84	292	188	64	16	42	264
22	13	F	92	96	104	68	62	91	573	610	106	48	49	102	0.7	0.2	29	142	142	100	5.0	4.6	92	146	75	51	35	54	154
23	11	F	88	92	105	67	48	72	540	293	54	45	45	100	0.5	0.2	40	142	140	99	4.2	4.4	105	140	70	50	16	14	88
24	32	F	71	88	124	61	69	113	842	610	72	45	49	109	2.2	0.7	32	121	120	99	3.6	3.6	100	126	30	24	25	54	216
Mean	44		101	96		78	75		847	806		45	44		0.9	0.7		140	139		4.4	4.3		140	101		40	44	
Per cent of control				95			96			95			98			78			99			98			72			110	
Mean per cent of control					96			99			96			99			81			99			99			75			122

Key: C: Control observations—average of three 10 minute periods. An: Observations during anesthesia—average of two 10 minute periods.

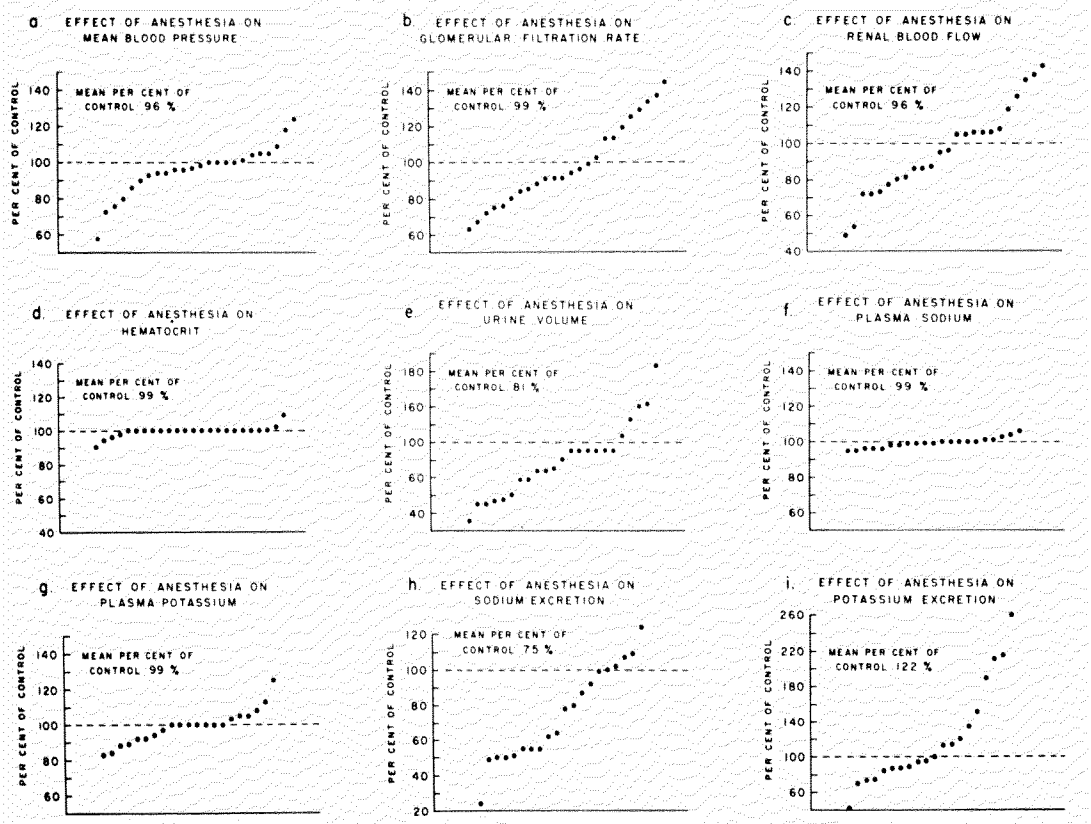

FIG. 1. Graphs *a* through *i* illustrate range of effects of light general anesthesia on renal hemodynamics in 24 patients before major cardiovascular operations. The per cent change for each patient has been plotted and the mean indicated.

minute and the Heidbrink ether vaporizer set between 4 and 6. The administration of ether-oxygen with succinylcholine and with frequent emptying of the rebreathing bag to eliminate cyclopropane was continued for an additional 20 minutes. Respiration was controlled in all patients. A Jefferson Ventilator was used in two-thirds of the patients. Ether was decreased, discontinued or removed when hypotension or cardiac arrhythmia appeared. Vasopressor agents were avoided during this study. Approximately 30 minutes following induction of anesthesia and after at least 20 minutes of ether-oxygen, the patient was assumed to be in a reasonably steady anesthetic state. Ether administration was reduced (Heidbrink vaporizer reading 2–3) and the anesthesia measurement period begun. A total of 100–300 mg. of succinylcholine was administered from induction of anesthesia to the end of the anesthesia period.

The anesthetic being studied here was essentially light ether-oxygen supplemented with succinylcholine, a technique which we have used in more than 3,000 cardiac and vascular surgical procedures. No measurement was made of the arterial ether concentration in these patients. However, in a group of 14 female patients less than 40 years of age who were anesthetized by an identical technique for a variety of gynecological procedures, the mean arterial ether concentration 30 minutes after induction was found to be 49.7 ± 1.27 mg. per cent (range 19.7–85.3).[11] It is likely that the mean arterial ether concentration in the patients in this study was significantly less than this since many were older and all suffered from cardiac or vascular disease. The administration of ether in these patients

was often discontinued or performed intermittently because of the development of hypotension. The data collected were considered as a unit since no significant differences were found when analyzed for age, sex, or type of surgical procedure subsequently performed.

Results

The data are summarized in table 1. The mean age for the 24 patients was 44 years with a range from 11 to 67 years. The average mean blood pressure before operation was 101 mm. of mercury, reflecting the frequency of preoperative hypertension in this group. During anesthesia blood pressure was maintained at 96 per cent of the control level (fig. 1a). Glomerular filtration rate averaged 78 ml. per minute before induction of anesthesia and was sustained at 99 per cent during anesthesia (fig. 1b). The mean control renal blood flow for the group was 847 ml. per minute and remained at 96 per cent during anesthesia (fig. 1c). Urine volume showed a slight reduction (81 per cent) during anesthesia, which was not statistically significant (fig. 1e). Plasma sodium and potassium were unaltered (fig. 1f and 1g). Urine sodium excretion was reduced 25 per cent but this was not statistically significant ($p > 0.4$) (fig. 1h). Potassium excretion rose 22 per cent but this also was not statistically significant ($p > 0.4$) (fig. 1i).

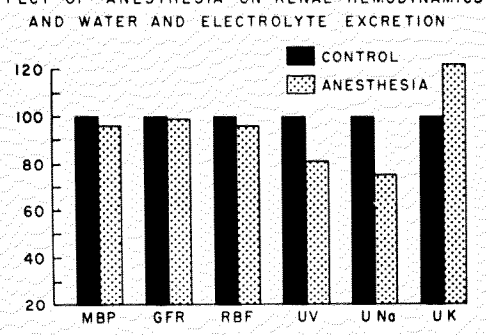

Fig. 2. Graphs illustrate mean effects of light general anesthesia on renal hemodynamics and water and electrolyte excretion in 24 patients. Changes in blood pressure (MBP), glomerular filtration rate (GFR), and renal blood flow (RBF) were not significant. Moderate depression in water (UV), and sodium excretion (UNa) with an elevation in potassium excretion (UK) suggest adrenal cortical activity although these alterations were not statistically significant.

Although the moderate depression in sodium and water excretion and elevation in potassium excretion had no statistical significance, some adrenal cortical activity is suggested (fig. 2).

Comment

Some previously reported studies indicating suppression of renal function during general anesthesia may not be entirely valid because operative procedures preceded or were concomitant with the period of observation.[3, 4, 8] Despite this, evidence suggests that any general anesthetic sufficient to maintain third stage anesthesia significantly reduces renal blood flow, glomerular filtration and urine volume.[1, 2, 7, 14, 17-20] On the other hand, it has been demonstrated in the dog that light anesthesia with ether or cyclopropane produced no depression in renal plasma flow and glomerular filtration rate [4] and that thiopental, even in large doses, did not depress renal function.[1] The effects of narcotics used for premedication are similar. The antidiuretic effect of morphine is well documented.[5, 6, 9, 10] The renal effects of meperidine used in this study have not been as thoroughly evaluated as those of morphine but suggest a similar action.[8, 13]

Considering the renal depressant effect of drugs for premedication and anesthesia together with the water and salt retention associated with any major surgical procedure, it is not surprising that many anesthesiologists and surgeons tend to restrain the administration of intravenous fluids during operation. The data presented here showing that light anesthesia with the liberal use of muscle relaxants permits nearly normal renal function are most significant in this regard. Evidence continues to accumulate that an adequate urinary output protects the kidney when it is exposed to insult.[12, 15, 21] Such insults are likely during operations which may be associated with hemorrhage, transfusions, tissue trauma, dehydration and hypotension. Therefore it is important that urinary output be maintained during such operations. In addition to protecting the kidney, an adequate renal function can serve to help maintain acid-base balance during anesthesia and operation.

The observations in this study were made between 30 and 60 minutes following induc-

tion of anesthesia and the changes in renal function were found to be minimal. One can infer that no greater change would have been observed if the study could have been prolonged.

Summary

The renal depressant effect of deep general anesthesia has been observed clinically and experimentally. With the availability of muscle relaxants there has been a trend in clinical anesthesia toward the use of minimal quantities of general anesthetic agents and increasing quantities of muscle relaxants. With such anesthesia, no significant alteration in renal function was found in a study of 24 patients prepared for major cardiovascular operations.

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