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Microhematocrit : its evolution and use : with special reference to serial determinations

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THE MICROHEMATOCRIT, ITS EVOLUTION AND USE, WITH SPECIAL REFERENCE TO SERIAL DETERMINATIONS

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TABLE OF CONTENTS

I. Introduction

The measurement of the packed cell volume, also called the hematocrit, of the venous blood has long been recognized as a useful aid in the study of blood in a large number of clinical conditions. However, this valuable tool is seldom used when dealing with infants and small children because of the difficulty of obtaining samples of venous blood. Many alternative methods for measuring the hematocrit devised over the years required either capillary or very small quantities of venous blood. Most of these procedures have had drawbacks, either in design or in application that have prevented them from gaining widespread acceptance. Since then, the Guest-Siler technique has been devised and fully evaluated.

This thesis is designed to give concise information concerning the history and basic physiologic aspects of the microhematocrit as well as to evaluate one of the current theories on blood volume regulation. The theory that hemodilution occurs within a matter of minutes instead of over a longer period of time has previously been concluded. Several attempts have been made to put this theory to use. Serial microhematocrits at spaced intervals have been thought helpful in evaluating blood and fluid replacement in operative patients. This thesis will attempt to illustrate in a series of cases the possible usefulness of this procedure.

II. History of the Hematocrit

Not long after Harvey discovered the circulation of blood and Malpighi realized the capillary networks of organ systems, great men of science have attempted and in many instances succeeded to explain the "Milieu Interne" of Claude Bernard, how it acts to maintain hemostasis. As well, to begin with, men like Welcker in the early 1800's attempted to measure accurately the blood volume of the human circulatory system. His studies involved exanguination and flushing out the system. In 1882 carbon monoxide labeled hemoglobin was accomplished by Gre'haut and Quinquand. Haldane and Smith used colorimetric titration depending on the matching of blood containing carbon monoxide with blood free of carbon monoxide to which the dye, carmine, had been added. Subsequently, Van Slyke and Salveson devised the gasometric method which in one of its various forms was used by others following them (11).

Along with the advent of more progressive methods and advanced medical knowledge came the introduction of determinations of packed cell volume. The significance of its relative constancy was recognized by Hedin and Blix in 1890, at which time it became known as the hematocrit (34). The following year, Daland developed a method for hematocrit determinations which consisted of two graduated capillary tubes and a small hand centrifuge. From Daland's original thesis came the foundation upon which other investigators laid more reliable methods.

There became known two categorically separate techniques for hematocrit determinations. The macro-method, perfected by Winthrobe in 1929, and thence one of the most universally accepted techniques (33). This technique consisted of the graduated tube centrifuged at high speeds for periods up to one-half to one hour (12, 20, 34). However, several men prior to this time realized the inconvenience and wasted time the method involved as advancing knowledge and desire for speed as well as efficiency cried for simplicity. The microhematocrit was introduced in 1916. This technique took two developmental routes (22). Capillary tubes sealed at one end (Epstein, 1916; Ponder and Saslow, 1930; Mason, 1934; Smith, 1936; Gruneberg, 1942; Meyerstein, 1942; Smith, 1944; Harris, Gilding and Smart, 1951; Sabine and Nikolai, 1952) and capillary tubes open at both ends (Gram and Norgaard, 1923; Van Allen, 1925; Guest, 1938; Kato, 1938 and 1940; Miller, 1939; Hamre, 1940; Benndítt, Straube and Humphreys, 1946; Shils, Sass and Goldwater, 1952) (10, 12, 15, 20, 31, 32, 34). Ponder and Saslow (1930) have reviewed many of the above methods and discussed their faults (30). Haden (1930) maintained the macro-method best (13). The use of anticoagulants was introduced by Gram and Norgaard in 1923 (10), and Rosahn in 1931 used heparinized tubes.

In the last paragraph we have demonstrated only some of the important work that has been done. Lending to the development of the microhematocrit, many facts have been proven. There are

many yet that are not universally accepted. With the advent of this method arose many doubts as to its validity and technicians, who had by then fully realized the value of Winthrobe's macro-method, were reluctant to desert this well established procedure for something new. Men like Guest and Siler (1934) proved the reliability of the microhematocrit using either capillary or venous blood (21, 22, 25). The method, because of its simplicity and low cost, became more and more widely accepted. Men like Strumia, Guest and McIntroy are responsible for the development of the most effective methods of microhemato-crit determination (34). Today, Guest and Siler's improved method of open ended, disposable microcapillary tubes is used routinely in this institution.

Guest and Siler's work was followed by McGovern and others (21) who proved the reliability of the finger stick capillary blood technique. These men were able to reproduce their results a significant number of times. Subsequent micro-hematocrits run on the capillary blood of the same individual at the same time revealed a coefficient of variation of from 1 to 3 percent as compared to 1 to 2.7 percent when the Winthrobe method was used. These men compared the microhematocrit of capillary blood to the Winthrobe method using venous blood and found in 100 patients that the microhematocrit levels closely approximated the Winthrobe hematocrit levels throughout the

observed range. They found also that the Winthrobe venous blood hematocrit yielded significantly higher packed cell volume than either of the microhematocrit methods (p less than 0.001). The difference, though statistically significant, was so small that it was without practical significance. Thus, it was found that on the basis of their findings, the microhematocrit levels could be predicted from Winthrobe levels or vice versa. These levels will be very close to, if not identical with, the observed values. They cite the formulas:

Microhematocrit of capillary blood = -0.91 / 0.98 (Winthrobe hct.)

Microhematocrit of venous blood = 1.47 / 0.93 (Winthrobe hct.)

Winthrobe hematocrit = 6.2 / 0.88 (microhematocrit of capillary blood)

Winthrobe hematocrit = 2.1 / 0.98 (microhematocrit of venous blood)

Accepted normal values for the microhematocrit are amenable to the same wide variation in different institutions as are the values for the micro-method of Winthrobe. One may generalize, with good cause, and settle on an average value applicable to man and woman. One study of 94 healthy males showed their average hematocrit to be 44.8 (range of 39.2 to 50.4). Similarly, in 100 healthy women, the average was 41.2 (range of 36.2 to 46.2). This was determined in milliliters per 100 ml. of blood. In a

similar study of 180 men, the average was 46.9 (range of 42 to 52) and in 24 women, 40.1 (range of 34 to 46) determined as milliliters per 100 ml. of blood (3). These values are commonly expressed in percent.

At the University of Nebraska Hospital the accepted range of normal hematocrits is 40 to 54 percent in males and 37 to 50 percent in females.

III. Physiology of Blood Volume Regulation

The basic nature of blood volume must be understood when the attempt is made to explain shock and similar capillary phenomena. Experiments regarding controlled hemorrhage have revealed many of the now well accepted facts. Loss of 25 to 30 percent of the blood volume may produce no significant reduction in blood pressure. Padhi and others in 1958 were able to draw several conclusions regarding shock after their work on 5 groups of five kilogram dogs. The dogs were able to tolerate 15 to 20 percent blood loss without significant drop in blood pressure, but they showed a fall of 10 to 15 percent in the pulse volume after only 5 percent blood loss and a fall of 90 percent after 35 percent loss in circulating blood volume (26).

In 1870 to 1875, Fischer first noted the fall in blood volume in shock with its corresponding vasoconstriction and decreased blood flow through the less essential organs. Krough

in 1922 found that temporary oxygen lack caused increased capillary permeability, causing irreversible stasis within fifteen minutes. Walter Cannon in the 1920's postulated that lowered oxidation with subsequent decreased heat production and temperature drop caused capillary atony, increased viscosity of blood and transudation of plasma across the capillary membrane which then resulted in stasis, a diminished cardiac return and cardiac hypoxia. Thus was cardiac energy and output also decreased. Moon distinguishes between shock and hemorrhage. "When an uncompensated disparity between the volume of blood and the volume capacity of the vascular system results from hemorrhage, the blood will show dilution; when it results from dilatation and permeability of the capillaries, hemoconcentration will be present." (24).

Even without hemorrhage shock may be accompanied by a fall in blood volume. Certain phenomena occurring as the result of neural or humoral mechanisms such as the alteration in osmotic balance of the blood or the alteration of the permeability of vessel walls brought about by toxins, drugs or infection may allow plasma transudation to the extravascular spaces and a resulting diminished blood volume. In such a physiologic state of hemoconcentration we see the earliest detectable manifestation of shock and have the most accurate index of its severity. The microhematocrit will allow the degree of hemoconcentration to

be disclosed.

More rapid and greater proportionate increases in plasma as compared to red cell volume are seen. Evidence of these facts are demonstrated when the blood volume is reduced in massive hemorrhage. As bleeding occurs, fluid begins to enter the circulation from the extravascular spaces. This was previously believed to be a phenomenon which took several days. Recently, it has been found that hemodilution can occur within minutes after hemorrhage; the expansion of the plasma volume buffering the loss to maintain blood volume (17, 18). Thereafter, over a longer duration of days or weeks, the red cell volume is gradually restored (6, 8). Pareira and others (27, 28), working with rats which were submitted to rather heavy blood loss, measured plasma volumes at 12, 24, 48 and 72 hours after hemorrhage was instituted. These men found that 50 percent of the plasma volume was replenished within the first 12 hours. The hematocrits were lowest at this point. Plasma protein concentration and plasma volume changes occur before 12 hours. Plasma volume, in this series, calculated from the blood volume with radiochromium, was 93 percent of the control value at 2 hours, 101 percent at 4 hours, and 108 percent at 8 hours after hemorrhage. During this time, red cell mass showed no tendency toward replacement. Thus, shifts between filtration and reabsorption of fluid in the capillary bed occur rapidly so that

great shifts in plasma volume may occur in a short time when there is a shift in osmotic and hydrostatic forces. Control for this regulating mechanism, according to current concepts (29), lies in the midbrain, with the anterior hypothalamic centers controlling water output via ADH (antidiuretic hormone) and the posterior diencephalic centers, possibly including the pineal, controlling sodium diuresis.

Plasma volume, we may conclude, is influenced by the following systems: (1) red cell volume, (2) serum protein concentration, which, if low, causes a decrease in effective osmotic pressure, and (3) body salt concentration, which, if low, causes the extracellular fluid compartment to shrink. The rate of hemodilution varies with other factors: (1) the amount of extracellular fluid available for hemodilution (i.e., in malnutrition or dehydration there may be no hemodilution), (2) rate of blood loss (the faster the hemorrhage, the faster the hemodilution), (3) vasodilatation contributes to the ease of transcapillary filling of the plasma volume (thus, in anesthesia, more rapid changes are seen with gaseous or volatile agents tending to cause vasodilatation) and (4) lower systolic blood pressure which will allow the fluid to penetrate the vessel wall more readily and thus establish equilibrium between the intra- and extravascular compartments (18).

IV. Experimental: Use of Serial Determinations

A. Introduction

One of the microhematocrit's most recent uses is that of serial determinations at spaced intervals to evaluate patients as to fluid replacement following surgery. It has been desirous to attempt to demonstrate a possible usefulness in many routine operative cases. As was mentioned earlier, previous work has disclosed that hemodilution can occur within a matter of minutes instead of hours or days (11, 27). "Serial hematocrit determinations consequently reflect blood loss and replacement more accurately than blood volume determinations" (18). Albert, et al. have stated that "the red cell volume is the only stable element of blood, therefore, it serves as a reliable index of blood loss" (2). The same also admitted that there seems to be little correlation between the actual red cell volume measured and the hematocrit. A great discrepancy was noted in patients with an apparently normal or adequate hematocrit. The depression by drugs, (i.e., general anesthetic agents), resulting in loss of normal vasomotor tone, may reveal a pre-existing hypovolemic state. In surgery, hypovolemic states with normal hematocrits may be seen in : (1) hypothermia, (2) hypertensive disease, (3) pheochromocytoma, (4) vasopressor effects, and (5) acute blood loss. In this experiment, with the use of serial microhematocrits, we have attempted to follow the ever

changing intravascular picture. We wanted to discover for ourselves what value, if any, this method had as a tool for the surgeon and anesthesiologist.

B. Methods of Experimentation

1. Selection of Materials

Preselected subjects were used in this experiment based in no way upon either history or physical status of the patient, but on the type of operative procedure. Operations that were purporting to be major, indicating possibility of considerable if not excessive blood loss and where such indications guided the surgeon to obtain crossmatching for whole blood replacement during the operation, were selected. Upon such patients serial microhematocrit determinations were performed both during the operation and a relative period of time postoperatively.

2. Apparatus

The capillary tubes used were heparinized, manufactured by Biological Research, Inc. of St. Louis and measured according to their specifications 1.2 - 1.4 mm. in diameter and 75 mm. in length. These were used in all the cases in this series. Sealing of the open end was accomplished by "Critoseal" plastic putty giving a flat water-tight plug.

Two centrifuges were used, both especially designed for microhematocrits here described of the improved

Guest and Siler method. Both were designed to exceed 11,000 rpm. and had a head radius of about 9 centimeters*. Each contained a timer allowing centrifugation for the recommended five minutes.

Reading was done to the nearest whole percent presuming possible errors due to failure to achieve uniform and adequate packing of the cells and errors in reading (16). In such instances errors up to one percent were anticipated. Apparatus were of two types: International Equipment Company, Micro Capillary Reader using illuminated background and magnification of the tube, and the less accurate Clay-Adams mechanical hematocrit tube reader constructed of a flat frame supporting a top and bottom plate and housing a gear mechanism which operates a rotating graduated dial read through a window. This gear system is attached to a reading arm which is adjusted to the meniscus of the capillary tube. The second apparatus is unquestionably prone to errors in reading. The reading arm, constructed of a plastic material was found to be somewhat pliable. The gear mechanism just described was found to have considerable play. Subsequent readings of the same tubes resulted in readings with up to one percent variation.

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*(a) International Equipment Company (IEC)

(b) Adams Company

3. Procedure

Twenty-two patients were selected. They were divided into two groups: (1) those patients undergoing elective general surgery where no great quantity of blood loss was anticipated and (2) those patients who underwent emergency surgery or endured considerable blood loss, who may have suffered injury or pathological hemorrhage. Each of these two groups were subsequently divided into two smaller groups depending upon the method used for obtaining the blood samples. (See Table I). Initially the greater number of patients were followed both in the operating suite and the recovery room by obtaining blood from finger puncture. This was accomplished using sterilized disposable hemolets. Great care was taken to obtain clean dry skin and free flow of blood in all cases. Single samples were taken using a different finger than the one before. The alternate approach was the attempt to provide venous blood for sampling. This was accomplished by the use of number eighteen spinal needles inserted well into a large vein, usually the anticubital vein, and removing the stilette to obtain the samples. The latter method was decidedly more cumbersome. Surgical draping lead to inaccessibility and in very long procedures, after several samplings were accomplished, the needles commonly became obstructed with clotted blood. Thus in order to complete the series using venous blood, venipunctures were

necessary. This was done with #25 needles.

TABLE I

	CAPILLARY BLOOD	VENOUS BLOOD
Patients undergoing elective general surgery	10	5
Patients undergoing emergency surgery or those who were subjected to considerable blood loss.	5	2

Samples in both series were taken at approximately fifteen minute intervals unless a considerably long operation was being performed, then samples were taken at half hour intervals. In all cases reported, preoperative base-line hematocrits were performed. The time of the sampling was recorded on the prepared sheet along with simultaneous recordings of estimated blood loss and fluid replacement. Blood pressure and pulse rates were not recorded because of the previously disclosed fact of their invalidity in estimation of blood volume deficit (26), and as well, it is not the purpose of this paper to disprove the thesis.

Capillary tube samples were immediately sealed but not immediately centrifuged. Permitting these tubes to sit up to three and four hours undisturbed had no noticable

effect on the results. Any small difference that could be anticipated was accounted for in the allowance of one percent error in readings. However, in most cases, it was customary to centrifuge the samples four at a time, making such information as was obtained available to the surgeon and the anesthesiologist.

C. Results

Serial microhematocrit determinations were performed on 22 surgical patients. The results in this series are presented in Table II.

Case 1: T.C. was a 56 year old, widowed, white male whose history is stippled with minor medical and surgical illnesses. However, the patient was presently hospitalized because of chronic alcoholism and intermittant left upper quadrant pain and hematemesis. The patient's bleeding was not remedied by conservative medical management. He underwent a gastrojejunostomy six days following admission. The operation lasted 2 hours, during which time he lost an estimated 85 cc. of blood. From the beginning of the procedure 0.3% sodium chloride in 5% dextrose and water was administered intravenously. Serial microhematocrits were done before, during and up to 2½ hours following the operation. No remarkable change in hematocrit was observed. See Figure 1.

Case 2: J.D. was a 69 year old, married, white male, admitted to University Hospital because of severe intermittant

Table II

Results of 22 cases studied showing estimated blood loss (EBL), fluid replacement (FR), and microhematocrit (Hct.) readings.

TIME (min.)		0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
	(hr.)					1				2				3				4				5
CASE #																						
1	EBL	0	10	20	30	50	55	70	75	85												
	FR	0	100	200	375	550	560	575	600	650	675	685	700	725	750							
	Hct.	30	30	33	33	34	35	36	26	33	35	32	33	35	36			33				
2	EBL	0	20	60	130	400																
	FR	50	100	175	350	400	500	650	900													
	Hct.	38	37	38	40	39	40	42	40					35								
3	EBL	0	50	80	200	300	325															
	FR	90	125	150	175	200	225	275	300													
	Hct.	45	45	44	43	44	42	41	41					40					42			
4	EBL	0	0	50	75	125	250	300	400	500	600											
	FR	0	50	100	160	225	25*	150	300	400	500	550		650				1000				
	Hct.	44	47	45	42	47	45	47	47	46	46	44		44				43				
5	EBL	0	75	200	250																	
	FR	25	125	130	150	250	375	475														
	Hct.	36	35	39	35	36	34	35														

* whole blood started and recorded separately

Table II (continued)

TIME (min.)		0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
	(hr.)					1				2				3				4				5
CASE #																						
6	EBL	0	10	50	90	110	130	150	160													
	FR	0	60	90	130	160	210	230	260	270	320											
	Hct.	41	42	41	41	39	40	39	45	43	42							42				
7	EBL	0	20	45	75	105	140	160	200	225												
	FR	0	50	100	125	135	150	165	200	225	250	260										
	Hct.	44	44	46	43	44	45	45	44	42	45	44						44				
8	EBL	0	0	30	40	50	75	150	210	250												
	FR	0	100	125	150	160	180	220	250	260	270	290	320									
	Hct.	40	39	39	41	40	38	38	40	40	39	40	40							39		
9	EBL	0	5	20	30	50	100	140	150	200	240											
	FR	25	40	50	75	100	125	140	150	165	175	190	210	225								
	Hct.	46	45	46	46	44	44	45	45	43	44	43	42	43				43				43
10	EBL	0	10	40	100	150	175	200														
	FR	0	25	45	75	100	120	160	190	220	250					450				500		
	Hct.	45	46	45	46	43	44	45	45	43	43	42				43				42		
11	EBL	0	100	120	130	140	160	200	210	215	220											
	FR	20	40	60	75	100	125	140	160	180	200	225										
	Hct.	43	43	41	43	44	43	43	42	43	43	41						43				

Table II (continued)

TIME (min.)		0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
	(hr.)					1				2				3				4				5
CASE #																						
12	EBL	0	50	75	100	120	150	180	220	240	260	330	400	440	480	510						
	FR	50	80	120	150	165	180	200	225	25*	50	100	125	170	200	240	275	300				500
	Hct.	40	43	43	42	43	41	42	43	42	40	41	41	40	41	42	40	41				40
13	EBL	0	40	80	90	110	120	130	160	175												
	FR	0	25	40	90	125	150	170	190	215	225											
	Hct.	45	45	46	42	45	43	44	44	44	45	43						43				
14	EBL	0	10	30	50	55	65	75	80	130	150	175										
	FR	0	25	40	60	75	85	100	150	160	180	220						500				
	Hct.	48	46	46	47	48	46	46	45	46	46	44						45				
15	EBL	0	50	100	140	180	240	300	310	330	350	360	375									
	FR	50	75	100	125	150	175	200	250	290	340	360	375			500						
	Hct.	46	48	46	45	47	46	46	47	45	46	44	45			44						
16	EBL	0	20	50	60	65	80	100	120	130	135	150										
	FR	10	25	50	75	100	120	150	175	190	210	225										
	Hct.	39	39	40	41	39	40	39	38	39							39					
17	EBL	0	75	200	250	300	320	340	350	375												
	FR	50	100	125	150	185	225															
	Hct.	48	46	48	47	46	46	47	46	46				45								

Table II (concluded)

TIME (min.)		0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
	(hr.)					1				2				3				4				5
CASE #																						
18	EBL	0	20	25	40	50	60	100	140	160	220	240	300	400	500	650						
	FR	50	75	100	20*	60	100	125	150	175	225	250	275	300	340	360		420		500		
	Hct.	38	38	39	38	37	38	38	39	38	36	37	36	37	38	38		37		37		
19	EBL	0	40	80	120	140	160															
	FR	80	120	160	180	220	260							500								
	Hct.	44	44	43	43	42	43							42								
20	EBL	0	25	50	60	70	100	200	250	300	380	440										
	FR	25	50	70	90	120	_															
	Hct.	48	48	46	47	48	47	45	46	45	46	46		45								
21	EBL	0	0	50	60	80	160	250	300													
	FR	0	50	75	100	140	180	200	225													
	Hct.	40	45	44	45	43	44	43	43				42					41				
22	EBL	0	10	40	60	90	120	150	250	350	400	500	550	600	700							
	FR	75	125	150	160	180	190	210	225	250	25*	60	100	150	200			500				1000
	Hct.	46	47	45	46	48	46	46	47	46	45	46	44	45	46			45				45

lower abdominal pain, weight loss and a history of several incidences of bright red blood per rectum. Physical examination revealed a very thin, poorly nourished man. Hemoglobin at the time of admission was 12 grams percent. Barium enema studies showed a filling defect in the rectosigmoid area. The patient was prepared for abdominal perineal resection. Baseline microhematocrit was 38 percent. The abdomen was opened. After exploration, due to the extensive malignant involvement, only paliative colostomy was performed. Serial microhematocrits were done on venous blood up to 1½ hours after the completion of the operation which lasted 1 hour and 15 minutes. There was relatively no significant change in hematocrit during this period. See Figure 2.

Case 3: B.K. was a 65 year old, married, white, female, whose previous history was complicated by recurrent pelvic inflammatory processes and several operations which resulted in the absence of both ovaries, tubes and uterus. Prior to admission to University Hospital the patient experienced episodes of lower quadrant pain and obstipation. She was operated and found to have partial large bowel obstruction due to multiple adhesions. A colostomy was performed. Her baseline microhematocrit was 45 percent. Serial determinations were done. Blood loss exceeded replacement of 0.3% sodium chloride in 5% dextrose and water at the end of the 1½ hour procedure. The

diagram in Figure 3 shows areas of diagonal lines where, for that period, blood loss exceeded fluid replacement. Hematocrit, however, failed to show significant change up to 2 hours after the end of the operation.

Case 4: C.H. was a 73 year old, widowed, white, male, whose complaints were related to bright red blood per rectum noticed 2 years prior to admission and thought to be due to hemorrhoids present for many years. The patient noticed, secondarily, considerable weight loss and gradual loss of energy during that time but ascribed these to "ageing". He denied obstipation but had relied upon heavy daily doses of laxatives for the last several years. Physical examination revealed an emphysematous and malnourished man. Barium enema disclosed the presence of extrinsic and intrinsic bowel lesions. An abdominal perineal resection was performed. Baseline microhematocrit was 44 percent. The patient received 225 cc. of normal saline and 2 units of whole blood within a four hour period. The procedure lasted $2\frac{1}{2}$ hours. Serial microhematocrits were taken up to $1\frac{1}{2}$ hours after the completion of the operation. These showed a very slight drop that may or may not be significant. See Figure 4.

Case 5: A.H. was a 34 year old, negro, female, whose state of health had been relatively impervious to disease except for recurrent peridontal infection as a result of inadequate diet and poor oral hygiene. She was recommended for total alveo-

lectomy and admitted to University Hospital. The operation was performed with considerable blood loss for this type of surgery. Baseline microhematocrit was 36 percent. Intravenous 0.3% sodium chloride in 5% dextrose and water was started. A #18 gauge spinal needle was inserted in the anticubital vein and samples were drawn in microcapillary tubes every 15 minutes. The operation was completed in one hour. Determinations were made up to 2 hours following the completion of the procedure. Except for a slight rise to 39 percent after one half hour of surgery, the level stabilized near baseline values. No significant change was seen.

Case 6: M.K. was a 61 year old, obese, white, female, whose history of the present illness dates back 2 years. At that time she noticed flatulence and transcient episodes of left upper quadrant pain following meals. She noted aggravation after ingestion of fatty foods. Because pain was only of minor severity, abstinence of these foods was followed by a period of relatively good health. However, one week prior to admission, the pain became severe, radiating around the side to the inferior border of the right scapula. X-rays were compatible with acute calculus cholecystitis. The patient was operated and an acutely inflamed gallbladder was removed. Baseline microhematocrit was 41 percent. The patient received 0.3% sodium chloride in 5% dextrose and water throughout the procedure. Serial micro-

hematocrits, continued for 2 hours after the 2 hour operation, failed to reveal significant alterations in hematocrit level.

V. Conclusion

Twenty-two patients that underwent surgical procedures were submitted to serial microhematocrit studies. The attempt to evaluate whether this use of the microhematocrit is a reliable tool for the surgeon or anesthesiologist has been made. Six sample cases were illustrated with accompanying graphs. The cases were of minor operative procedures where serial microhematocrits were done. Results showed no significant change of red cell volume. The surgeon and anesthesiologist gained little from the readings. They benefited only from the initial microhematocrit determination.

The six illustrative cases represented results obtained in the remaining 16 cases. Serial microhematocrits failed to reveal changes in red cell volume occurring during the operation that would indicate hemodilution or hemoconcentration. Instances where blood volume clinically showed a decrease, the hematocrit showed insignificant alteration. Thus, simultaneous loss of plasma and cellular elements was not reflected by hematocrit change. Compensatory hemodilution that would result in a drop in hematocrit did not occur during the operations. Microhematocrits during this period were of no relative value. The only consistent drop that may or may not have been significant occurred in the

Fig. 1: Blood loss, fluid replacement and Microhematocrit on the patient in case #1.

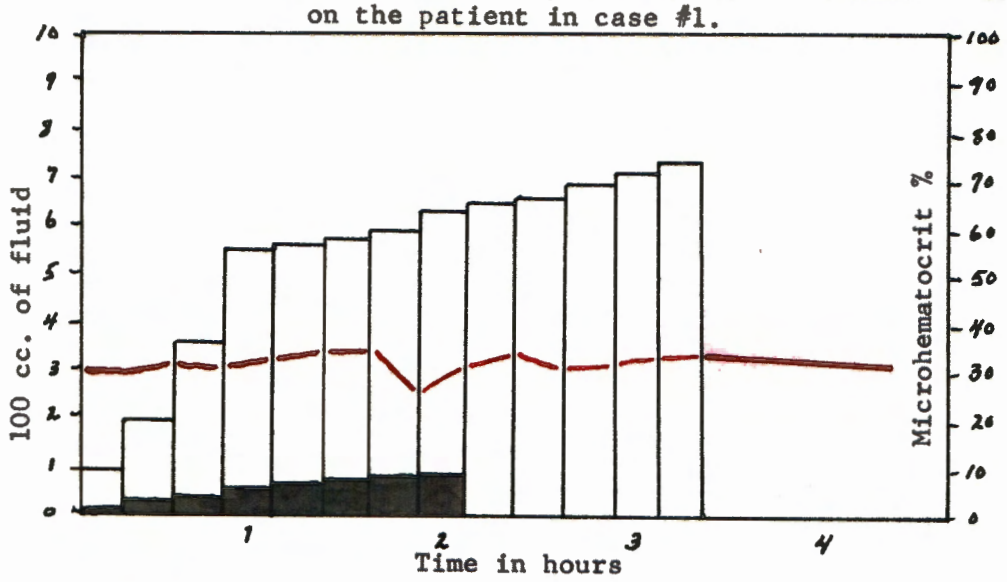


Fig. 2: Blood loss, fluid replacement and Microhematocrit on the patient in case #2.

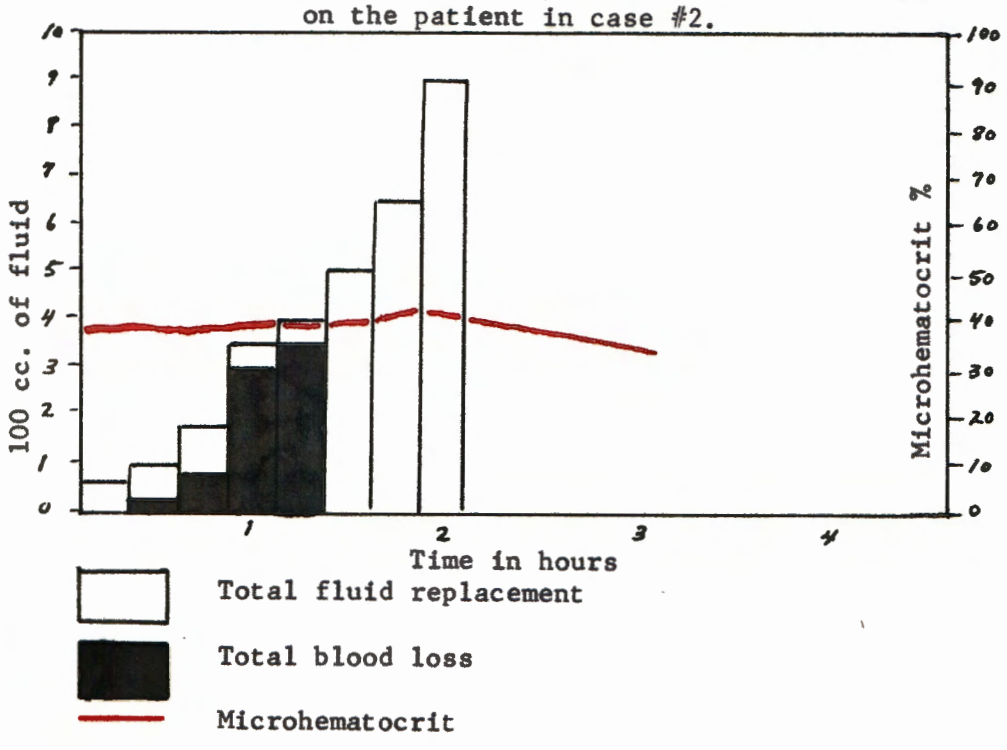


Fig. 3: Blood loss, fluid replacement and Microhematocrit on the patient in case #3.

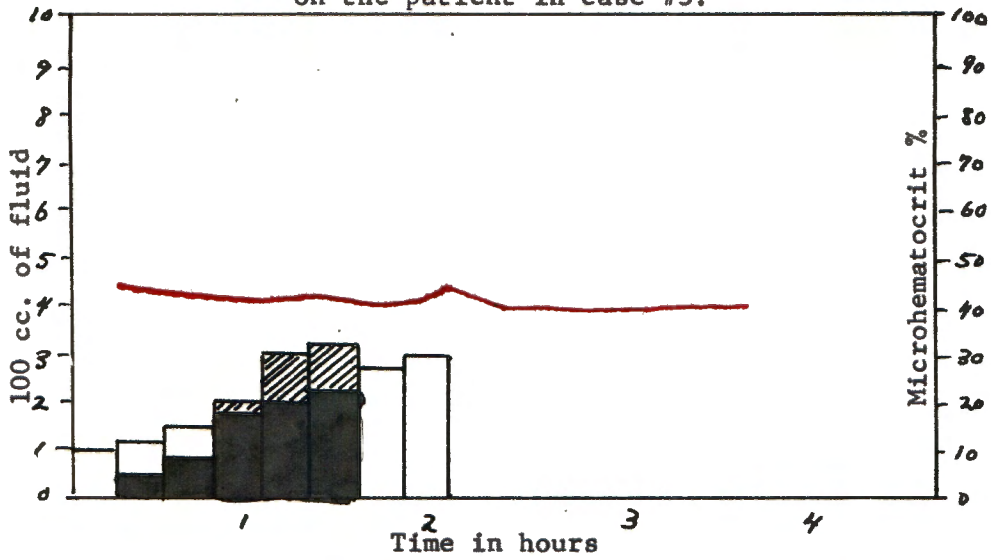
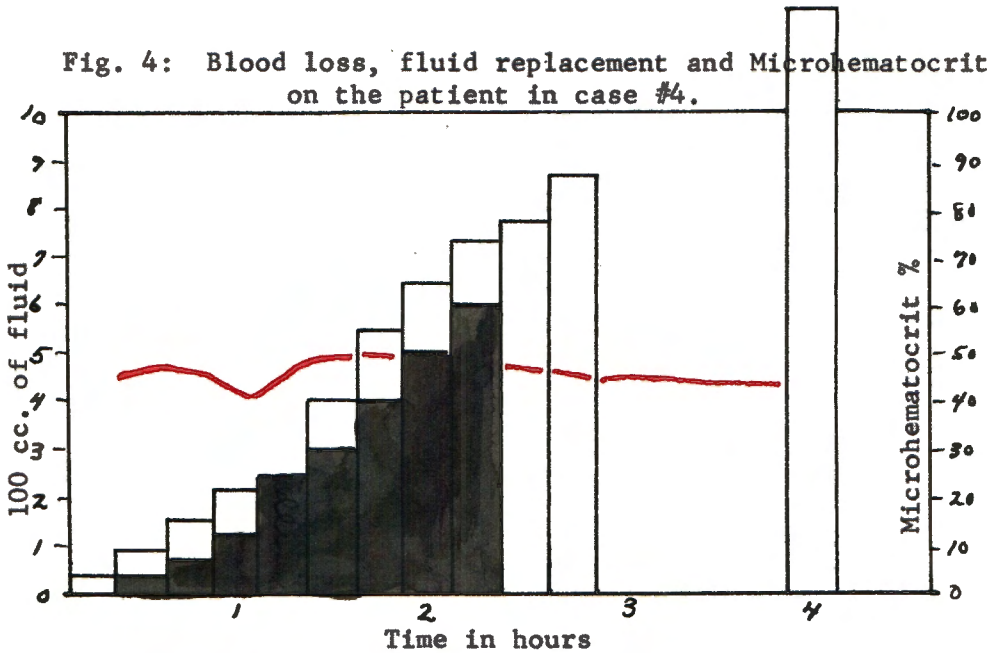


Fig. 4: Blood loss, fluid replacement and Microhematocrit on the patient in case #4.



Total Fluid replacement

Total blood loss

Blood loss in excess of fluid replacement

Microhematocrit

Fig. 5: Blood loss, fluid replacement and Microhematocrit on the patient in case #5.

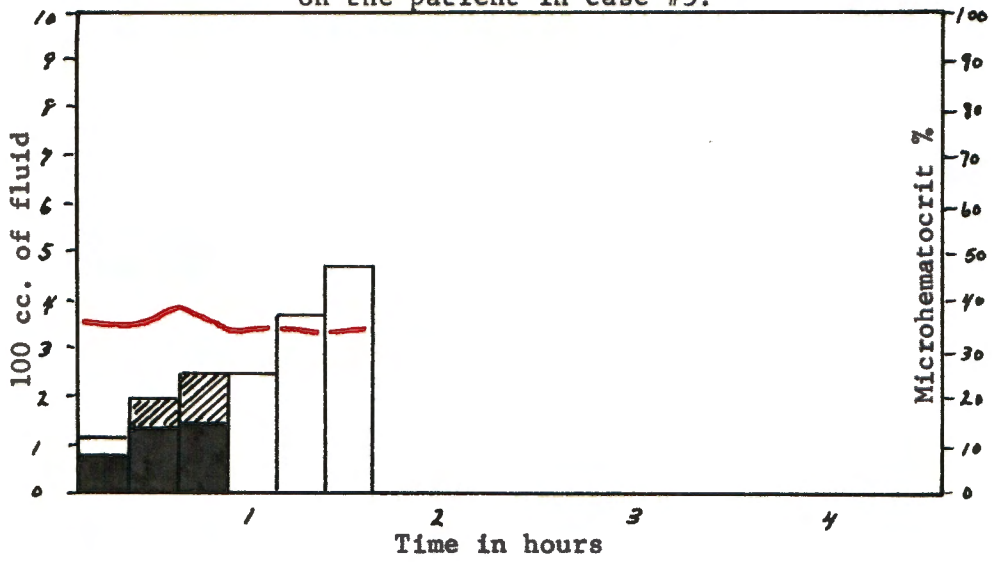
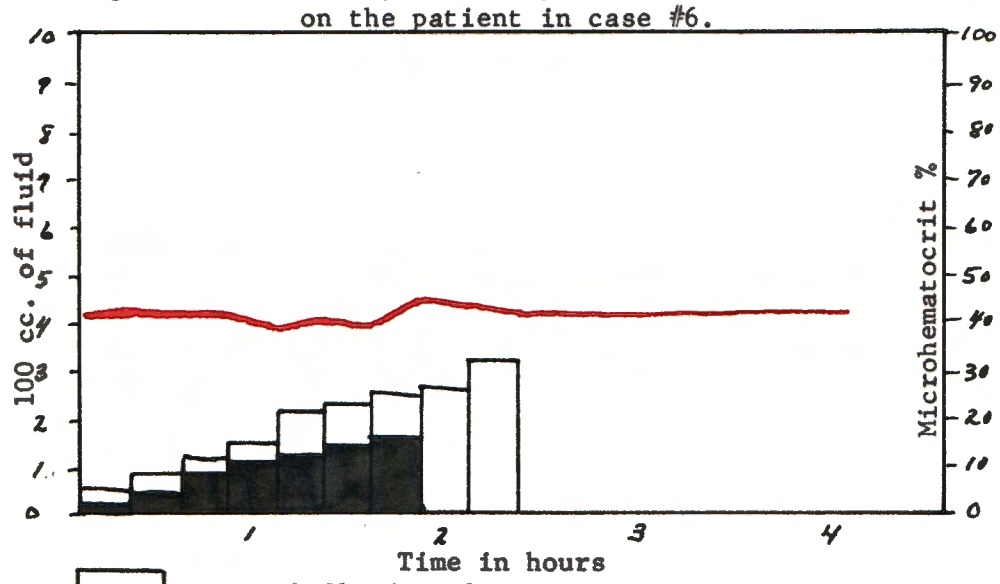


Fig. 6: Blood loss, fluid replacement and Microhematocrit on the patient in case #6.



Total fluid replacement

Total blood loss

Blood loss in excess of fluid replacement

Microhematocrit

majority of cases after the second hour following completion of the operation. This tends to illustrate that hemodilution, though it may occur rapidly, that is, within several hours, occurs at a degree which is not readily measurable. The change could be attributed to error in obtaining, centrifuging or reading the blood samples.

Errors in techniques applied were unavoidable. Although consistent technique by one individual was used, accidents did occur. In all of the cases it would have been to the advantage of the experimentor to make certain that temporary storage of capillary tubes be in a safe place. On two occasions, carelessly placed tubes were knocked to the floor and spillage of plasma was believed to have occurred in one or two of the tubes. Other tubes were broken in the fall and had to be discarded, making it necessary to repeat the sampling.

Errors in reading were avoided as much as possible by careful technique, but consequently were inevitable. Only one tube sample was taken at the sampling period. Each tube was read only twice. These errors may have been avoided by using more than one tube with each determination, then reading them perhaps three times instead of twice. This may have decreased the percent of error. However, such was anticipated and included in the 1% variations in reading during the experiment. Changes to this degree were thought to be insignificant.

In several of the cases in this series, venous blood was used instead of capillary blood. It was not our purpose to evaluate and compare these two techniques. No conclusions can be drawn as to whether one is better than the other. However, in cases where venous sampling was done, results were similar to those obtained with capillary blood. That is to say, there was no significant microhematocrit change any more illustrative of blood or red cell volume change than that shown with capillary microhematocrits. One may conclude only that it is certainly more cumbersome to use venous blood rather than capillary blood for serial microhematocrit determinations.

VI. Summary

For many years physicians have been aware of the value and simplicity of the hematocrit of circulating blood, otherwise known as the packed cell volume. It has been described as one of the most accurate, simple and inexpensive methods for the evaluation of anemic states and the changes existing in such conditons. As well, within recent years, the constant desire to simplify has brought into existence a counterpart to the hematocrit, the microhematocrit. Paralleling the work by Winthrobe on the macro-method perfected in 1929, progressively more reliable methods were found for a simpler and less expensive technique. This method was readily available, utilizing capil-

lary blood in much less volume than venous blood. Results of experimentation have been strongly supporting the reliability of the Guest-Siler microcapillary method as compared to Winthrobe's method.

Capillary and hemophysiologic phenomenon have been illustrated in the past in simulated shock-like situation in laboratory animals. Further and more extensive work has been accomplished in the human subject. It has long been known that when there is a red cell deficit, a phenomenon called hemodilution occurs. This results in a shift in fluid and electrolytes from the extracellular compartment to the intravascular fluid compartment. The shift acts as a buffer, fluid compensating for red cell loss. This occurs relatively soon after hemorrhage. Several investigators believe this occurs much sooner than previously believed.

In this paper, the attempt was made to demonstrate any such phenomena described above by the use of serial microhematocrit determination. It was our desire to see if such information, when obtained, was of any value to the surgeon or anesthesiologist in routine operative cases as to blood and/or fluid replacement.

Twenty-two patients who underwent operations of various forms were subjected to study. Serial microhematocrits were done on all cases. These were accomplished at spaced intervals

throughout the operation and for some time thereafter. Care and consistency were used. Results failed to show significant hematocrit alterations. The value of such serial studies in routine cases was concluded to be minimal in this series. However, because of the small series, no general conclusions could be drawn. Any changes seen could have been explained as due to errors in reading. Changes were not reflected in the micro-hematocrit determinations during simultaneous drop in both plasma and red cell volume.

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