

New Formula (22/17) for Calculation of the Total Amount of Intravenous Fluids Given for Pediatric & Neonatal Surgical Operations Weighing up to 20 Kg or 5 Years Age

Abstract

Introduction: A new formula (RH) for calculation of intra operative fluids given in neonatal & pediatric life threatening surgical operations from 1 kg – 20 kg body weight (or 1 day – 5 yrs age) was explained in this study.

Aim of the Study : To find a simple , correct, & easily applicable formula to avoid any unwanted dangerous faults in calculation of fluid requirements in all types of neonatal & pediatric surgical operations from 1 kg – 20 kg body weight (or 1 day – 5 years age) especially for juniors or early post graduated doctors dealing with these age group (or weights).

Patients: (5000 Patients) including neonates, infants & pediatric age group presented to CWTH/Medical city/Baghdad for different types of surgical operations were enrolled in this study divided to 3 groups (Group A) Life threatening and emergency conditions 2300 patients, (Group B) Major & super major elective operations 700 patients & (Group C) Different types of minor to moderate elective surgical operations 2000 patients.

Methods: In this new formula intra operative fluid requirements calculated as:

- *Pre existing deficit (Fasting): 20 ml/kg this amount is divided over 3 hours: $\frac{1}{2}$ the amount given in the 1st hour of operation and $\frac{1}{4}$ the amount is given for each the 2nd & 3rd hours of operations.
- *Maintenance fluid requirements: 4 ml/kg/hr for all weights up to 20 kg.
- *3rd Space replacement: 8 ml/kg/hr for major & super major operations & 4 ml/kg/hr for minor operations.

Results: By comparison of this new formula with most of other references and other anesthesia text books fluid formulas regarding this aspect the results is that the difference in the total amounts of fluid requirements per hour was minute and regarded as negligible difference.

Conclusion: *This new (RH) formula has been used for years (2005-2015) in neonatal & pediatric anesthetic department in CWTH/ Baghdad Medical City for 5000 neonates, infants & pediatric patients without any complications.

- This new formula is correct, safer, simpler & easily applicable than other formulas.
- The most important point in this new formula, is that it can be summarized by just 2 numbers (22- 17), 22ml/kg for the 1st hr. & 17 ml for the 2nd & 3rd hrs of operation time for major operation.

Keywords: Pediatric anesthesia; New formula; Intraoperative fluid; Fasting; Third space

Review Article

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Introduction

In all anesthetic department dealing with pediatric and neonatal age groups, most of the patients in this age group present to the surgical theatre for emergency or life threatening surgical operations threatening and in need for urgent surgical interference . One of the main anesthetic challenges in these patients is the low birth weight (starting from 2kg or 3kg) especially premature

and neonates, with life threatening congenital anomalies (e.g. Congenital intestinal obstruction, Imperforated anus, Tracheo-esophageal Fistula (T.E.F) ,Congenital Diaphragmatic Hernia (CDH),.... also total blood volume in these patients is limited in amount (80-90 ml/kg)[1].

The classical formulas for calculation of fluid administered during neonatal and pediatric surgical operations used by

different pediatric anesthetic references and most Anesthetic Text Books [1-4] are as follows:

- *Calculation of pre-existing deficit (Fasting amount (F)).
- *Maintenance fluid requirement (Maintenance (M)).
- *Replacement fluid for 3rd space (3rd space amount).

Fasting amount (Deficit):

Preoperative fluid deficit is mainly due to omitting the oral intake of milk and other fluids and soft foods as a part of preparation for surgery.

Fasting time: 2 hrs for clear fluid, 4 hrs for breast milk, 6 hrs for formulated milk and food [1].

This deficit fluids are usually replaced with isotonic and balanced salt solutions (e.g Lactated Ringer's injection) or (½ Normal Saline), keeping in mind that hypotonic solutions replacement can lead to severe hyponatremia that may lead to brain damage [1,2].

Fasting amount calculated as follow;

The maintenance amount of the fluid calculated is multiplied by the fasting hour's time, meaning:

Fasting amount = (maintenance amount ml/ kg) X (6 hrs. fasting).

Then they divide this fasting amount of fluid over the 1st three hours of surgical operation as:

½ of the calculated amount given in the 1st hour of operation, ¼ of the amount given in the 2nd hour of operation & ¼ of the amount given in the 3rd hour of operation [2,3,5,6].

Maintenance amount (4-2-1 formula):

Maintenance fluid volume determined based on patient weight, and the classical calculation of maintenance fluid requirement using the "4-2-1" rule was adopted from Holliday and Segar's in 1957 [7,8].

And with calculation of electrolytes in breast milk, they add 0.2% saline to 5% dextrose, and later on by adding Lactated Ringer fluid to replace the 3rd space loss intraoperative [4]. Giving 5% dextrose alone should be discouraged because the sugar is rapidly metabolized resulting in increased volumes of free water, so it is ultimately equivalent to administration of free water [3]. Also they discuss another concept that based on the metabolic requirement for patient at rest where by 1 ml of water is required to metabolize 1 Kcal. (8). Type of maintenance fluid still controversial. 5% Dextrose with ¼ N/S may be a better choice in neonate because of their limited ability to handle sodium load. Children up to the age of 8 years required 6 mg/kg /min glucose to maintain euglycemia (40-125 mg/ d) [4].

4 - 2 - 1 Rule for calculation the maintenance fluid requirement is as follow:

- 4 ml/kg for 1st 10 kg body weight,
- 2 ml/kg for 2nd 10 kg body weight

1 ml/kg for each kg above 20 kg body weight [2-4,6,8].

3rd Space Requirement :

3rd space loss refers to fluids which is lost from the circulation during surgical operation, because surgery is associated with transfer of isotonic fluid from the intravascular space to a nonfunctioning extravascular compartment [3].

Some of this fluid from edema in the area of operation some may be lost into the bowel and there may be losses from evaporation. The more major the surgery the more 3rd space replacement fluid will be required.

A lot of formulas used here, some of these formulas calculate 3rd space loss as:

1 - 10 ml/kg /hr according to the type of pediatric surgery operation

Or 2-15ml /kg /hr according to the type of pediatric operation [4].

This represent much more difficult calculation than the maintenance amount because they give a wide range in amount of fluid calculated per kg (1-10, 2-12 or 2-15 ml/kg), this may lead to dangerous calculation mistake, [3,4,5,7] especially with less skill or less trained personal like junior anesthetic doctors and post- graduate students in pediatric anesthetic departments.

Note: some references use other formulas for calculating these 3rd space losses in pediatric age group such as:

- e.g: 2- 8 ml/kg/hr for minor & moderate types operation.
- 6 - 12 ml/kg/hr for major & super major operations.

This later formulas is more acceptable, and for comparison with the new formula in this study, a mean of this later formula will be chosen for 3rd space amount which is:

- 4ml /kg /hr for minor & moderate operations
- 8ml /kg /hr for major & super major operations.

Aim of the Study

To find a correct, safe, simple, easily applicable & understandable formula to avoid all unwanted dangerous mistakes in calculation of fluid requirements in all types of premature, neonatal & pediatric surgical operations (including emergency and life threatening surgeries) & from 1 kg - 20 kg body weight (or 1 day - 5 years age) especially for juniors or early post graduated doctors dealing with these age group (or weights).

Patients and Methods

Patients

Five thousands (5000) patients of neonatal out of about (15000) of infant and pediatric age group presented to the pediatric surgical and anesthetic department in Children Welfare Teaching Hospital (CWTH)/ Medical City /Baghdad in the last 10 years (2005- 2015) for different types of life saving emergency operations or for elective surgery were selected to be enrolled in this study, these cases are arranged in 3 groups (A, B and C). Group

A and B include: special, super major & major surgical operations and for life saving and emergency operation (group A) or elective major & super major operations (B). Group C include a different types of elective minor to moderate surgical operation (Table 1).

Our hospital (CWTH) is one of the biggest tertiary pediatric hospitals in our country and receive referral of difficult and special pediatric and neonatal cases from all over the country.

Table 1: Types and Numbers of Surgical Operations.

Types of Surgical Operations		Number of Patients	
Group a	. Tef*	220	2300
	. Cdh*	100	
	. Pyloric stenosis	230	
	. Intestinal Obstruction (congenital or not)	1750	
Group b	. Pull through operation	700	
	. Psarp*		
	. Renal & hepatic tumors (removal)		
	. Scrocoxygeal teratomas (removal)		
	. Biliary atresia		
	. Choledochal cysts		
Group c	. Closure colostomy	2000	
	. Splenectomy		
	. Excisional biopsies		
	. Inguinal & umbilical hernia		
	. Hydrocele		
	. Undescended testicles		
	. Anorectal surgeries		

*tef: tracheoesophageal fistula

*cdh: congenital diaphragmatic hernia

*psarp: posterior sagittal anorectal plasty

Group A: 2300 cases of life threatening and emergency operations these include: Tracheo-oesophageal Fistula (TEF) 220 cases (mean age: 7 days), Congenital Diaphragmatic Hernia (CDH) 100 cases (mean age: 20 days), Congenital Pyloric Stenosis 230 cases (mean age: 17 days) and Intestinal Obstruction (whether congenital or not) 1750 cases (age: premature, neonates & infants). The ASA (American Society of Anesthesiologist) physical status of this group ranging from ASA III, IV & V.

Group B: 700 patients presented with different types of major operations including (Biliary Atresia, Choledochal Cyst, Pull Through operation, Posterior Sagittal Ano Recto Plasty (PSARP), Sacrocoxygeal Teratoma, Splenectomy, Closure Colostomy, Willm's Tumors). The age of patients in this group ranging from few months to 5 years. The ASA physical status of this group is ASA III & IV.

Group C: 2000 patients presented for elective operations of different types like: (Inguinal and Umbilical Hernia, Hydrocel, Undescended Testis, Rectal surgeries & excisional biopsies). The age of patients in this group ranging from few months to about 5 years, and the ASA physical status is ASA I & II.

Method

Different age groups with different weights starting from 1kg, 3kg, 5kg, 10kg, 15kg & 20kg for different types of surgical

operations were enrolled in this study, and the amount of intra-operative fluid requirement for the 1st, 2nd and 3rd hours of surgical operation time is calculated for both formulas (4-2-1 classical formulas and the new formula), then a comparison of the results in calculation is done (Table 2).

In the new formula (RH Formula) the intraoperative fluid is calculated as follows:

Pre existing deficit (Fasting amount): is by giving

3ml /kg for 7 hours fasting so

Fasting amount = 3ml x 7 hr x kg = 21ml/kg

This approximated to 20ml /kg for easy calculation, this amount of fluid (similar to the classical formulas) also divided to 3 parts:

1/2 the amount given in the 1st hour of operation, 1/4 the amount given in each 2nd & 3rd hour of operation.

Maintenance fluid requirement: here only one number is used which is 4ml / kg /hr; this number used for all pediatric age and weight (up to about 5 year or 20 kg) (9).

Note: this is an important gain (in this new formula), only one number used to avoid the difficulty in calculation of maintenance amount (4-2-1 rule) in the classical formulas.

3rd Space calculation

For 3rd space fluid amount, the same numbers used for both formulas (4-2-1 formula) and the (New 22/17 formula) to decrease the difference in the total amount of fluid calculated by the tow formulas, so the following numbers used for 3rd space calculation:

- 4ml /kg/hr for minor and moderate surgical operation.
- 8ml/kg/hr for major and super major surgical operation.

**For Minor and Moderate surgical operation

The difference in the total amount of intra operative fluid requirement is related to the difference in amount of 3rd space loss, because a less amount of fluid is given (4ml/kg/hr).

So the total amount of fluid requirement in the 1st hour for a minor and moderate surgical operation in the new formula as follow: 10ml (Fasting) + 4ml (Maint.) + 4ml (3rd space) = 18 ml/kg/hr. Which is (approximated to 17ml/kg/hr)

Summery

(It is 22/17)

This new formula can be summarized by:

Fasting (F) amount is 20 ml/kg divided to (10ml, 5ml and 5ml)

For the 1st, 2nd and 3rd hours of operation time respectively.

Maintenance (M) amount, only one number used which is :

4 ml /kg /hr for all ages & weights (1 day -5yrs. or 1kg -20kg bw).

3rd Space amount: 4 ml/kg/hr. minor & moderate operation 8 ml/kg/hr. major & super major operation.

So for a baby with a major or super major operation, the total amount of fluid needed during his operation is calculated by this new formula is:

$$1^{\text{st}} \text{ hr } 10\text{ml (F)} + 4\text{ml (M)} + 8\text{ml (3}^{\text{rd}} \text{ sp.)} = 22\text{ml/kg}$$

$$2^{\text{nd}} \text{ hr } 5\text{ml/kg} + 4 \text{ ml/kg} + 8 \text{ ml/kg} = 17 \text{ ml / kg}$$

$$3^{\text{rd}} \text{ hr } 5\text{ml/kg} + 4\text{ml/kg} + 8 \text{ ml/kg} = 17 \text{ ml / kg}$$

Note: ** for MINOR and Moderate operation we give: 17 ml/kg for the 1st hour.

**Types of fluids used in this new formula is the same that

used in the classical formulas (Normal Saline, Glucose Saline & Ringer's solutions).

Results

From comparison tables (Table 2) it is obvious that the difference in amount of fluid calculated for these 2 formulas is only minute and regarded as negligible difference (only : about 1ml/kg for the whole 1st hour of operation) especially when dealing with small weight babies. Also it is a simple and easily calculated formula.

Table 2: Comparison between the classical (4-2-1) & the New formula (for total Intra operative fluid calculated in neonatal and pediatric patients).

Types of Surgical Operation	Weight	Operation Time	4-2-1 Formula total fluid amount	New Formula total fluid amount	Difference ml/kg
Major Operation	1 kg	1 st hour	24 ml	20 ml	
		2 nd hour	18 ml	17 ml	
		3 rd hour	18 ml	17 ml	
Major Operation	3 kg	1 st hour	72 ml	66 ml	- 2
		2 nd hour	54 ml	51 ml	- 1
		3 rd hour	54 ml	51 ml	- 1
Major Operation	5 kg	1 st hour	120 ml	110 ml	- 2
		2 nd hour	90 ml	85 ml	- 1
		3 rd hour	90ml	85 ml	- 1
Major Operation	10 kg	1 st hour	240 ml	220 ml	- 2
		2 nd hour	180 ml	170 ml	- 1
		3 rd hour	180 ml	170 ml	- 1
Major Operation	15kg	1 st hour	320 ml	330 ml	- 0.6
		2 nd hour	245 ml	255 ml	- 0.6
		3 rd hour	245 ml	255 ml	- 0.6
Major Operation	20 kg	1 st hour	400 ml	440 ml	+ 2
		2 nd hour	310 ml	340 ml	+ 1.5
		3 rd hour	310 ml	340 ml	+ 1.5

Discussion

*The classical (4-2-1 rule) formula although it is mentioned in all pediatric and other anesthesia textbooks and references, this formula is difficult to calculate because 3 amount of fluids should be measured:

The Fasting (Deficit) amount + Maintenance amount + 3rd space loss amount. After that a summation of these 3 amounts is calculated for each hour of surgical operation time according to body weight, so it is obvious that it is difficult to calculate and apply especially for small weight babies like newborns and infants since that their blood volume is very small (80-90 ml/kg) with total blood volume of just (250-270 ml) in neonates. So even a small amount of extra fluid given due to a mistake in calculation may lead to dangerous outcome. Also in the newborn and infants renal function is immature, and they produce large amount of diluted urine and can become dehydrated if fasted for prolonged period of time [1].

For those reasons a very precise and accurate formula for calculation of the amount of fluids needed is necessary.

*This simple new formula (22/17) has been used for the last 10 years (2005- 2015) by (RH) in the neonatal and pediatric anesthetic department in CWT/ Medical City / Baghdad for more than five thousands neonates , infants and pediatric patients for different types of surgical operations as shown in this study without any complications .

*Different age groups with different weights starting from 1kg, 3kg, 5kg, 10kg, 15kg & 20kg for different types of surgical operations were enrolled in this study, and the amount of intra-operative fluid requirement for the 1st, 2nd and 3rd hours of surgical operation time in both formulas (4-2-1 classical formulas and the new formula) is calculated, then a comparison of the results in calculation is done (Table 2).

Table 3: Method for calculation of total amount of intraoperative fluids requirement for neonatal & pediatric patients by the 2 formulas.

The Classical (4-2-1) Formula	The New Formula
Fasting amount = Maintenance amount X 6 hrs. 4 ml/kg X 6 hrs. = 24 ml/kg (12,6,6) ml.	Fasting amount = 3 ml/kg X 7 hrs =21 or 20 ml/ kg (10,5,5) ml.
----- Maintenance = 4 ml/kg /hr. for 1 st 10 kg bw 2 ml/kg/hr. for 2 nd 10 kg bw 1 ml/kg/hr. for each kg above 20 kg	----- Maintenance = 4 ml / kg /hr. for all body weights up to 20 kg (& or up to 5 years
----- 3rd space amount = 4 ml/kg/hr. (for minor & moderate surg. op.) 8 ml / kg / hr. (for major & super major op.)	----- 3rd space amount = 4 ml/kg/hr. (for minor & moderate surg. op.) 8 ml / kg / hr. (for major & super major op.)

Table 4: The classical (4-2-1) formula for calculation of the total intra operative fluid in neonatal and pediatric patients.

Types of Surgical Operation	Weight	Operation Time	4-2-1 Formula
Major Operation	1 kg	1 st hour 2 nd hour 3 rd hour	24 ml 18ml 18 ml
Major Operation	3 kg	1 st hour 2 nd hour 3 rd hour	72 ml 54 ml 54 ml
Major Operation	5 kg	1 st hour 2 nd hour 3 rd hour	120 ml 90 ml 90ml
Major Operation	10 kg	1 st hour 2 nd hour 3 rd hour	240 ml 180 ml 180 ml
Major Operation	15kg	1 st hour 2 nd hour 3 rd hour	320 ml 245 ml 245 ml
Major Operation	20 kg	1 st hour 2 nd hour 3 rd hour	400 ml 310 ml 310 ml

This difference in amount of fluid given by these 2 formulas (as it is obvious in this comparison table) is only minute and can be regarded as a negligible difference.

* This new (RH) formula is a correct, safer, simpler, and easily applicable formula by which we can avoid any unwanted

dangerous mistake that may occur when using the classical (4-2-1) formula [1,3].

Table 5: The New (RH) formula 22/17 (for the total intra operative fluid calculated in neonatal and pediatric patients).

Types of Surgical Operation	Weight	Operation Time	New Formula
Major Operation	1 kg	1 st hour 2 nd hour 3 rd hour	22 ml 17 ml 17 ml
Major Operation	3 kg	1 st hour 2 nd hour 3 rd hour	66 ml 51 ml 51 ml
Major Operation	5 kg	1 st hour 2 nd hour 3 rd hour	110 ml 85 ml 85 ml
Major Operation	10 kg	1 st hour 2 nd hour 3 rd hour	220 ml 170 ml 170 ml
Major Operation	15kg	1 st hour 2 nd hour 3 rd hour	330 ml 255 ml 255 ml
Major Operation	20 kg	1 st hour 2 nd hour 3 rd hour	440 ml 340 ml 340 ml

*The most important point in this new (RH) formula is that can be summarized by just 2 numbers:

*(22 – 17): give 22 ml/kg as total fluid requirement for major & super major operation in the 1st hour of surgery in pediatric patients and 17ml/kg as total fluid requirement for the 2nd & 3rd hours of surgery. Also give 17ml/kg as total fluid calculation in the 1st hour for minor operation.

Conclusion

By a comparison with classical (4-2-1) formula (Table 5), the new formula can be used effectively for calculation of intra operative fluid requirements for all neonates, infants and pediatric patients up to 5 years (or up to 20 kg) , and for all types of surgical operation in this age group because;

- a) *It is safe, correct, simpler, and easily applicable than the classical formulas.
- b) *It has been used for thousands of neonatal and pediatric surgical operations without any complications.
- c) *It can be summarized by two numbers (22 – 17).

Recommendations

We recommend to learn and use this new (RH) formula (22/17) frequently as a routine formula for these weight (and ages) whenever needed especially in general hospitals or a non-specialized (pediatric and neonatal) centers and in any extraordinary situation when an urgent need for pediatric surgeries given by general or non-experienced anesthesiologist.

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