A FORMULA FOR THE DETERMINATION OF APPROPRIATE CHEST TUBE SIZE AND LENGTH OF INSERTION IN CHILDREN

Tamatey MN[1,2]; Tettey MM[1,3]; Edwin F[1,2]; Entsua-Mensah K[1]; Gyan B[1,4]; Okyere I[5]; Adzamli IK[1,] Adomako K[1,6]; Offei-Larbi G[1,4]; Aniteye EA[1,3]; Kotei DA[1]; Ofosu-Appiah EA[1,4]; Amoah K[1]; Ibrahim UE[1]; Adinku P[1]; Maishanu M[1]; Awodi J[1]; Osei EK[1]; Yao NA[1,7]; Sereboe LA[1,3]; Frimpong-Boateng K[1,8]

[1]National Cardiothoracic Centre, Korle-Bu Teaching Hospital, Accra, Ghana; [2]Department of Surgery, School of Medicine, University of Health and Allied Studies, Ho, Ghana; [3]Department of Surgery, University of Ghana Medical School, Accra, Ghana; [4]University of Ghana Medical Centre, Accra, Ghana; [5]Department of Surgery, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana; [6]37 Military Hospital, Accra, Ghana; [7]Department of Child Health, School of Medicine, University of Cape Coast, Cape Coast, Ghana; [8]Providence Specialist Hospital, Achimota, Accra, Ghana

Abstract

Objective: The study was carried out to develop a formula that uses the child's age or body surface area (BSA) to determine the appropriate size and length of the chest tube to be inserted.

Methodology: Children aged 12 years and below who had chest tube insertion at the National Cardiothoracic Centre from July 2015 to August 2016 were retrospectively enrolled into the study. The inclusion criterion was those who had the chest tube data recorded in their notes. This was the derivative cohort. The chest tube type used was SURUCATH ULTRA®. The BSA was calculated using the Mosteller formula. The statistical analysis was performed using Microsoft excel 2013. The data of the derivative cohort was plotted on a graph, and an equation was deduced from the graph, representing the data. This equation is the formula. The formula was then used to determine the appropriate chest tube size and length of insertion on a validation cohort from January 2021 to April 2022.

Results: In the derivative cohort, there were 50 children, 34.0% being males. The mean age was 4.2 ± 2.9 years. The weight ranged from 3.5 – 50 kg, the height ranged from 50 – 159 cm and the body surface area ranged from 0.2 – 1.5 m^2. In the validation cohort, there were 56 children, 48.0% being males. The mean age was 4.4 ± 2.8. The weight ranged from 5 – 40 kg, the height ranged from 54 – 152 cm and the body surface area ranged from 0.3 – 1.3 m^2. The outcome of the validation was good. The chest tubes functioned well and there were no chest tube-associated complications. The formulae obtained were S (FG) = A + 16, L (cm) = 0.3A + 3.5, S (FG) = 6B + 16, L (cm) = 3.5B + 3, where S is the size of the chest tube, A is the age in years, L is the length of insertion and B is the body surface area. The L is the length of the tube that has gone into the chest.

Conclusion: A formula has been developed to guide in determining the most appropriate chest tube size and length of insertion in children, using the age and body surface area.

Key words: *Formula, chest tube, size, length, children*

Introduction

The insertion of chest tubes is a very important procedure in clinical practice. It is a life-saving procedure, often inserted for therapeutic purposes. Even though it is a life-saving procedure, it is fraught with many complications, some of which become life-threatening if the necessary precautions are not taken. If the tube is too big there can be injury to the intercostal neurovascular bundle, and if it is too small also, it will not drain well. If the length of insertion is too short, it will not drain well. It may even cause a pneumothorax, with its attendant morbidity and mortality. If it is too long also, it can damage the lung and any structure in the mediastinum. Indeed, we have encountered several situations where chest tubes were inserted elsewhere, without much awareness of the appropriate size and length, leading to some complications. It is therefore very important to have an idea of the most appropriate size and length of the chest tube to be inserted, especially in children. Some formulae have being developed in medical practice to guide the correct positioning of endotracheal tubes and double-J stents in children using the age.[1, 2] Kopac also developed a formula for the estimation of the appropriate size of urinary catheter in children.[3] With chest tube insertion in children, however, there is no clear formula (a mathematical relationship) that uses the age or the body surface area (BSA) of the child to determine the appropriate size and length of the chest tube to be inserted. It is in this regard, we carried out this study to help develop a simple formula that provides a more

Corresponding Author: **Dr. Martin N. Tamatey**
National Cardiothoracic Centre, Korle-Bu Teaching Hospital, Accra, Ghana
Email Address: mtamatey@yahoo.com
Conflict of Interest: None Declared

precise guide to the clinician using the child's age or BSA.

Materials and Methods

The study had both a retrospective part and a prospective part. They were both carried out in the National Cardiothoracic Centre, Korle-Bu Teaching hospital. The retrospective part involved children aged 12 years and below, who had chest tube insertion for various procedures between July 2015 and August 2016, and the chest tube size and length were recorded in their notes. The selection of the size of the chest tube and length was based on the clinician's experience, since there was no guiding formula. And since this is a cardiothoracic centre where chest tubes are passed very frequently, and with good outcomes, the clinicians' choices provided reliable data.

The maximum age of 12 years was used because the Department of Child Health admits children up to the age of 12 years. The chest tube type used during the study period was SURUCATH ULTRA®, from Suru International PVT. LTD, Dahanu, India. The BSA was calculated using the Mosteller formula: BSA (m^2) = $\sqrt{(W \times H)/3600}$, where W is weight in kg and "H" is height in cm.[4] The statistical analysis was performed using Microsoft excel 2013. This included the means, standard deviations and the plotting of the graphs from the data obtained. The equations derived from the graphs became the formulae. The formulae were then used to guide in chest tube insertions in the validation cohort.

The validation cohort involved 56 children, also aged 12 years and below, who had various procedures between January 2021 and April 2022, and the chest tube parameters were recorded in their notes. Using the formula, the age was used to predict the appropriate chest tube size to be used (Table 2). The BSA was also used to predict the appropriate chest tube size to be used. The values were the same in most instances. Where there was a slight difference, the clinician had the option of using the Age-predicted value or the BSA-predicted value. The age and the BSA were again used to predict the appropriate lengths of insertion.

Results

There were 50 children in the derivative cohort, 17 (34.0%) males and 33 (66.0%) females. The mean age was 4.2 ± 2.9 years (0.4 – 11 years). The weight (W) ranged from 3.5 – 50 Kg, the height (H) ranged from 50 – 159 cm and the body surface area (BSA) ranged from 0.2 – 1.5 m^2.

Table 1: The derivative cohort

No	Age/ years	Sex	Wt/ kg	Ht /cm	BSA /m^2	Diagnosis	Size /FG	Length /cm
1	0.4	M	3.5	50	0.2	PDA	18	4
2	0.4	F	5.0	66	0.3	PDA	18	4
3	0.5	M	5.5	59	0.3	VSD	16	3
4	0.6	F	5.0	66	0.3	PDA	16	4
5	0.7	F	5.0	63	0.3	PDA	16	3
6	0.8	M	6.2	65	0.3	PDA	18	3
7	0.9	F	5.0	70	0.3	PDA	16	3
8	1.0	F	9.0	80	0.4	PDA	18	3
9	1.2	F	7.0	72	0.4	PDA	18	4
10	1.3	F	8.5	79	0.4	TOF	20	3
11	1.3	F	8.0	62	0.4	PDA	16	4
12	1.3	M	11.0	85	0.5	PDA	20	4
13	1.7	F	10.0	55	0.4	AVSD	20	4
14	1.8	F	5.0	77	0.3	PDA	20	5
15	2.0	F	9.0	88	0.5	PDA	20	4
16	2.6	M	12.0	94	0.6	VSD	20	5
17	2.7	F	10.2	92	0.5	PDA	16	4
18	2.8	M	13.0	97	0.6	VSD	18	4
19	2.8	F	17.0	106	0.7	PDA	20	6
20	2.8	M	12.0	94	0.6	PDA	18	3
21	3.0	F	12.0	97	0.6	VSD	18	5
22	3.0	M	10.5	96	0.5	TOF	18	3
23	3.0	F	12.0	97	0.6	PDA	20	4
24	3.0	F	8.0	92	0.5	PDA	18	4
25	3.2	F	11.0	95	0.5	VSD	20	4
26	3.2	F	10.5	94	0.5	PDA	20	4
27	3.5	F	12.0	78	0.5	PDA	20	4
28	4.0	M	17.5	108	0.7	VSD	18	5
29	4.0	F	11.0	111	0.6	PEF	24	6
30	4.6	M	14.0	108	0.6	TOF	20	4
31	5.0	F	19.5	112	0.8	PEF	24	6
32	5.0	F	20.0	112	0.8	PEF	24	6
33	5.0	M	14.0	109	0.7	TOF	18	4
34	5.0	M	11.0	98	0.5	CS	24	4
35	5.0	M	14.0	101	0.6	TOF	20	5
36	5.8	F	13.0	88	0.6	CS	20	4
37	6.0	F	20.0	97	0.7	TOF	20	4
38	7.0	M	18.0	117	0.8	MR	20	4
39	7.0	F	25.0	134	1.0	PT	20	5
40	7.0	M	23.0	126	0.9	TOF	20	6
41	7.0	F	25.0	132	1.0	BT	24	6
42	7.0	F	26.0	122	0.9	PDA	20	6
43	8.0	F	20.0	104	0.8	PDA	24	6
44	8.0	F	21.0	120	0.8	TOF	20	6
45	8.0	F	23.0	130	0.9	TOF	24	6
46	8.0	M	19.0	124	0.8	PDA	20	5
47	8.8	F	25.5	134	1.0	PDA	24	6
48	9.5	M	25.0	135	1.0	TOF	24	5
49	10.8	F	26.0	132	1.0	VSD	20	6
50	11.0	F	50.0	159	1.5	EPT	28	8

PDA-patent ductus arteriosus, **VSD**-ventricular septal defect, **TOF**-tetralogy of Fallot, **AVSD**-atrioventricular septal defect, **CS**-corrosive stricture, **BT**-bronchial transection, **PEF**-pleural effusion, **EPT**-empyema thoracis, **PT**-pneumothorax

The correlations between the age and chest tube size, age and chest tube length, BSA and chest tube size, BSA and tube length are shown from Fig. 1 to Fig. 4 respectively.

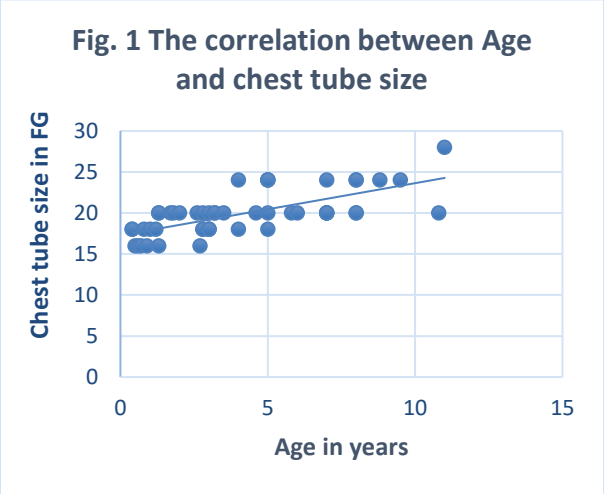

Fig. 1 *The correlation between Age and chest tube size. This is a plot of the size of chest tube and the age of the child that it was used for.*

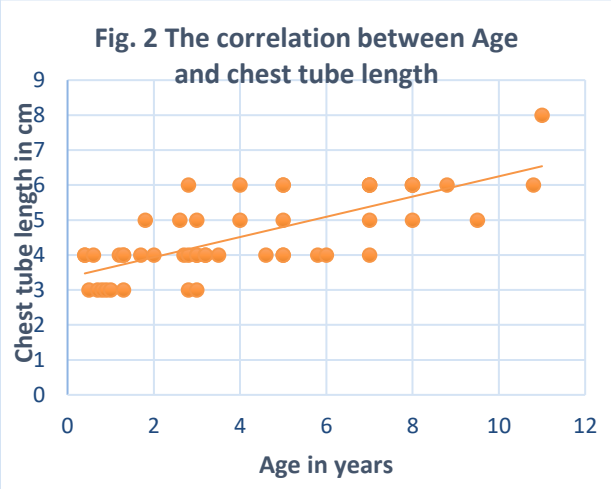

Fig. 2 The correlation between Age and chest tube length. This is a plot of the length of the chest tube inserted versus the age of the child.

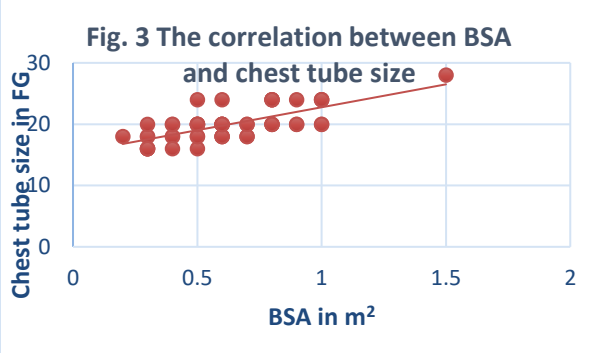

Fig. 3 *The correlation between BSA and chest tube size. This is a plot of the size of chest tube used against the BSA of the child.*

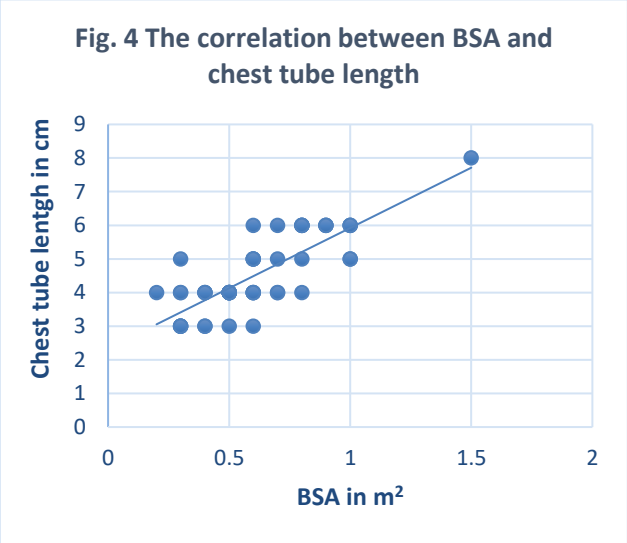

Fig. 4 *The correlation between BSA and chest tube length. This is a plot of the chest tube length inserted versus the BSA of the child.*

All the graphs were scatter diagrams, implying that the clinicians' choices were varied. But there were no chest tube-associated complications.

The formulae

1. The formula for determining the appropriate chest tube size using the age is **S (FG) = A + 16**, where S is the size and A is the age in years.

2. The formula for determining the appropriate chest tube length using the age is **L (cm) = 0.3A + 3.5**, where L is the securing length and A is the age in years.

3. The formula for determining the appropriate chest tube size using the BSA is **S (FG) = 6B + 16**, where S is the size and B is the BSA.

4. The formula for determining the appropriate chest tube length using the BSA is **L (cm) = 3.5B + 3**, where L is the securing length and B is the BSA.

The size obtained is approximated to the nearest even number, and the length obtained is also approximated to the nearest whole number. In the validation cohort there were 56 children, with 27 (48.0%) being males. The age range was 0.5 – 11 years, with a mean of 4.4 ± 2.8. The weight ranged from 5 – 40 kg, the height ranged from 54 – 152 cm and the body surface area ranged from 0.3 – 1.3 m^2.

Table 2: The validation cohort

No	AGE /Years	SEX	WT /Kg	HT /Cm	BSA /m^2	DIAGNOSIS	Tube Size Predicted By AGE	Tube Size Predicted By BSA	Actual tube Size used/FG	Tube Length Predicted By AGE	Tube Length Predicted By BSA	Actual tube Length used/cm
1	1.3	F	7	70	0.4	PDA	18	18	18	4	4	4
2	8.0	F	23	134	0.9	TOF	24	22	24	6	6	6
3	1.0	F	5.5	54	0.3	PDA	18	18	18	4	4	4
4	6.0	F	16	110	0.7	TOF	22	20	20	6	5	6
5	2.5	M	10	90	0.5	VSD	20	20	18	5	5	5
6	11.0	M	39	152	1.3	PEF	28	24	24	7	8	7
7	7.0	F	18	110	0.8	TOF	24	22	24	6	6	6
8	3.0	F	12	95	0.5	TOF	20	20	20	5	5	5
9	4.0	M	14	98	0.6	TOF	20	20	20	5	5	5
10	6.0	F	16	112	0.7	CS	22	20	20	6	5	5
11	6.7	F	20	110	0.8	TOF	24	22	24	6	6	6
12	1.6	M	15	82	0.5	PDA	18	20	18	4	5	5
13	9.0	M	29	130	1	VSD	26	22	24	6	6	6
14	7.0	M	18	116	0.8	TOF	24	22	24	6	6	6
15	3.0	M	10	97	0.5	TOF	20	20	20	5	5	5
16	3.0	F	9	90	0.4	TOF	20	18	20	5	4	4
17	6.0	M	18	110	0.8	TOF	22	22	24	6	6	6
18	1.4	F	9	70	0.4	PDA	18	18	18	4	4	4
19	6.0	M	18	110	0.8	TOF	22	22	24	6	6	6
20	5.0	M	14	110	0.6	TOF	22	20	20	5	5	5
21	5.0	F	15	105	0.6	AVSD	22	20	20	5	5	5
22	2.0	M	8	88	0.4	TOF	18	18	18	4	4	4
23	4.0	M	12	100	0.5	TOF	20	20	20	5	5	5
24	2.0	F	12	90	0.5	TOF	18	20	20	4	5	4
25	8.0	M	25	122	0.9	TOF	24	22	24	6	6	6
26	1.2	F	7	71	0.4	PDA	18	18	18	4	4	4
27	1.5	M	7	73	0.4	PDA	18	18	18	4	4	4
28	1.3	F	7	70	0.4	PDA	18	18	18	4	4	4
29	3.0	F	13	92	0.6	VSD	20	20	20	5	5	5
30	4.0	M	13	102	0.6	TOF	20	20	20	5	5	5
31	6.0	M	15	141	0.8	TOF	22	22	20	6	6	6
32	1.0	M	5	70	0.3	PDA	18	18	18	4	4	4
33	11.0	F	40	150	1.3	TOF	28	24	24	7	8	8
34	4.5	F	20	124	0.8	AVSD	22	22	20	5	6	6
35	3.0	F	11	90	0.5	VSD	20	20	20	5	5	5
36	10.0	M	22	143	0.9	TOF	26	22	24	7	6	7
37	3.0	F	12	80	0.5	TOF	20	20	20	5	5	5
38	6.0	F	15	100	0.6	TOF	22	20	20	6	5	6
39	0.8	M	7.5	65	0.4	PDA	18	18	18	4	4	4
40	5.0	F	16	110	0.7	TOF	22	20	20	5	5	5
41	6.0	M	20	127	0.8	TOF	22	22	20	6	6	6
42	6.0	F	16	110	0.7	TOF	22	20	20	6	5	6
43	2.0	F	9	82	0.5	PDA	18	20	20	4	5	4
44	0.9	M	9	75	0.4	PDA	18	18	18	4	4	4
45	5.0	M	21	110	0.8	TOF	22	22	24	5	6	5
46	7.7	M	24	123	0.9	FBI	24	22	24	6	6	6
47	3.0	F	9	98	0.5	PDA	20	20	20	5	5	5
48	7.0	M	24	124	0.9	TOF	24	22	20	6	6	6
49	3.0	F	13	88	0.5	TOF	20	20	20	5	5	5
50	0.5	F	5	78	0.3	PDA	16	18	16	4	4	4
51	1.0	M	7	79	0.4	PDA	18	18	18	4	4	4
52	9.8	F	20	115	0.8	PDA	26	22	24	7	6	7
53	5.0	M	15	104	0.7	TOF	22	20	20	5	5	5
54	2.5	M	8	70	0.4	PDA	20	18	20	5	4	5
55	3.0	F	13	83	0.5	TOF	20	20	20	5	5	5
56	2.0	F	10	75	0.4	PDA	18	18	18	4	4	4

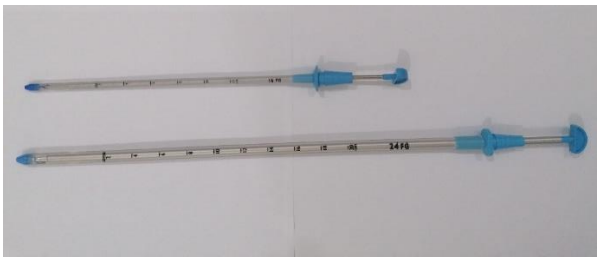

Fig. 5 *Sample of type of chest tubes used in the study.*

All the graphs were scatter diagrams, implying that the clinicians' choices were varied. But there were no chest tube-associated complications.

Discussion

Chest tube sizes are measured using French gauge (FG) in even numbers; 16, 18, 20, 22, 24, 26, 28, etc. This size refers to the external diameter of the tube. The numerical size, when divided by 3 gives the diameter in millimetres (mm). The thickness of the tube is 1.0 – 1.5mm. What determined the size of chest tube and length in the first place, was the experience of the clinician. The scatter diagram nature of the graphs was therefore not surprising. It implies that the clinicians' choices for the chest tube sizes and lengths were very varied. And yet they all obtained good results. A particular chest tube size was chosen for a number of ages. And a particular age can also take a number of sizes. The correlation developed from the graph represented a 'mean' of the choices. The formula was developed from the equation of the graph. It then serves as an appropriate guide. It is therefore not a rigid rule. It is easier to use the age than the BSA because using the age does not involve tedious calculations. But the BSA is more appropriate because it considers the size of the child by using the weight and the height. The size of the child correlates with the size of the intercostal space, which in turn has a bearing on the size of the tube that must be chosen and how far it must be pushed in.

Variations in the formula

Since the formulae have been developed from scatter diagrams, it means that slight variations in the equations will still work.

Intraoperative data

Most of the chest tubes were inserted in the theatre (intra-operatively). But this does not mean that the formulae are limited to only intra-operative situations. They can be applied in any clinical situation. The formulae are also not limited to only the diagnoses in the tables. They are applicable to any diagnosis in a child. All that is needed to apply the formula is the age or the weight and height of the child.

Conclusion

A formula has been developed to guide in the determination of the most appropriate chest tube size and length of insertion in children, using the age and body surface area. S (FG) = A + 16, L (cm) = 0.3A + 3.5, S (FG) = 6B + 16 and L (cm) = 3.5B + 3, where S is the size of the chest tube, A is the age in years, L is the length of insertion and B is the body surface area.

References

1. King BR, Baker MD, Braitman LE, Seidl-Friedman J, Schreiner MS. Endotracheal tube selection in children: a comparison of four methods. *Ann Emerg Med.* 1993; 22:530-534.
2. Palmer JS, Palmer LS. Determining the proper stent length to use in children: age plus 10. *J Urol.* 2007; 178:1566-1569.
3. Matjaž Kopac. Formula estimation of appropriate urinary catheter size in children. *J Pediatr Intensive Care* 2 2013; 177–180
4. R D Mosteller. Simplified calculation of body-surface area. *N Engl J Med*. 1987; 317:1098. doi: 10.1056/NEJM198710223171717.