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THE RULE OF 4'S: SAFE AND EFFECTIVE PLEURAL DECOMPRESSION AND CHEST DRAIN INSERTION IN SEVERELY INJURED CHILDREN

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ABSTRACT

The intersecting scenarios of multi-trauma, thoracic injury and traumatic cardiac arrest present some of the most demanding moments in paediatric trauma. For these reasons, decision support through teamwork, checklists, technology, and guidelines are central to ensuring quality paediatric trauma care. *The Rule of 4's* is a simple aide-memoire, which guides clinicians of all grades, expertise and distractedness in a reliable approach to injured children who require safe and effective emergency pleural decompression and timely insertion of a chest drain. *The Rule of 4's* enables these important therapeutic goals to be met through: (1) 4 steps in a 'good plan'; (2) 4^{th} (or 5^{th}) intercostal space as the basis for siting a 'good hole'; (3) 4 x uncuffed endotracheal tube size (4 x [Age/4+4]) to guide selection of a 'good tube'; and (4) 4cm mark for a 'good stop' to ensure the drain is in far enough *but not too far*.

KEYWORDS

Chest tube; Child; Pneumothorax; Practice Guideline; Thoracic Injuries

The intersecting scenarios of multi-trauma, thoracic injury and traumatic cardiac arrest present some of the most demanding and confronting moments in paediatric trauma. For these reasons, many of us will find ourselves battling to address life-threatening and time-critical needs of the severely injured child in exactly the cognitive and clinical arena where clear-headed decision-making is the exception rather than the rule. Therefore, decision support through teamwork, checklists, technology, and guidelines are central to ensuring quality paediatric trauma care [1]. *The Rule of 4's* is a simple aide-memoire, which guides safe and effective pleural decompression and chest drain insertion in severely injured children. *The Rule of 4's* has evolved from that organic evidence base nestled somewhere between the *Top Knife* [2] school of reference-light, experience-heavy trauma teaching and our contemporary, insatiable, thirst for the affirmation and security of citations and data.

This aide-memoire is designed as a consolidated reference document for use in paediatric trauma. We will now give credence to the notion that a picture is worth a thousand words, and take these 1000 words and more to outline the messages and actions recommended by *The Rule of 4's* (Figure 1).

A simple problem. A simple solution.

> *"There is no more neutrality in the world. You either have to be a part of the solution, or you're going to be a part of the problem."* **Eldridge Cleaver**

In the trauma setting, the 'simple problem' is one of an immediate threat to life or health due to a significant volume of air and/or blood in the pleural space. This threat may be actual or suspected, and the relative order of action and diagnosis confirmation will vary with the clinical setting. For this simple problem, the equally simple solution is to first make a **'good hole'** (i.e. *prompt pleural decompression*), and then to insert a **'good tube'** (i.e. *timely insertion of a chest drain*). Again, the rapidity and laterality of these interventions are determined by the child's clinical status. For example, traumatic cardiac arrest requires immediate and bilateral pleural decompression, which – *in children as in adults* – is best achieved by thoracostomy [3-6]. In children, chest drain insertion typically follows soon after thoracostomy, with the important caveat that the time and place of chest drain insertion must be consistent with the overall clinical priorities. Other trauma indications for pleural decompression and chest drain insertion allow clinicians to be more selective in side and less pressured in time, but no less required to ensure the safety and efficacy of their actions. Therefore, whatever the trauma situation and angst, we need a good plan and the **magic number FOUR** to guide and enable us to achieve all our therapeutic goals.

A good plan: 4 steps

The magic number for a good plan is **FOUR**: 4 steps to make a good hole, and 4 more for inserting a good tube.

Making a good hole

1. **Site:** with the arm at 90 degrees abduction, a safe and effective **site** for thoracostomy is chosen in the 'safe triangle' (Figure 2, see 'A good hole');
2. **Push:** blunt dissection with an artery (or mosquito) forcep to is used to **push** and spread through the intercostal muscles and enter the pleural cavity. Whilst bluntly dissecting, the proceduralist stabilises their hand with the tip of their forefinger strategically positioned at the hinge of the forcep (Figure 3). This position provides optimal ergonomics for dissection, and very importantly serves as a physical brake to guard against the instrument plunging dangerously into the chest at the moment the resistance of the intercostal muscles and pleura is overcome and the pleural cavity entered. Once in, open the forcep jaws to ensure the entry hole is wide and allow immediate and effective decompression of the pleural cavity. If the threat to life is tension from a pneumothorax or haemothorax, *this* is the moment the life is saved.
3. **Sweep:** a finger (or if intercostal space is too narrow, artery forcep or mosquito forcep) is carefully inserted to develop the tract and **sweep** the pleura clear of the entry point. This frees any obstructing pleura impinged by a nearby rib fracture, and ensures a clear path for both air/blood evacuation and chest drain insertion. You may observe a further gush of air and blood at this point, indicating your 'good hole' is now at its most effective.

4. **Keep:** intentional and mindful sweeping will help **keep** the hole open and tract clear, making re-accumulation of tension prior to chest drain insertion and/or difficulty with subsequent chest drain insertion much less likely.

Inserting a good tube

1. **Size:** an appropriate **size** (calibre) chest drain is chosen (see 'A good tube);
2. **Find:** with the drain tip controlled by an artery (or mosquito) forcep, use gentle pronation/supination movements of the tube tip and forcep to **find** your tract and hole again, which may take a moment despite the efforts to 'sweep' and 'keep' your good hole. Avoid the temptation to hook the forcep tip into a drain side hole, as this may make it difficult to release your grip or free the forcep from the drain (Figure 4). Please, *never* use a trocar. Trocars are associated with all manner of preventable, severe iatrogenic trauma, e.g. visceral and vascular injury, tube malposition and re-expansion pulmonary oedema [7, 8].
3. **Start:** having 'found' the tract and hole, open wide the jaws of the forcep holding the chest drain to release its grasp, and **start** advancing the drain into the pleural cavity. Remember, the life was saved by making your good hole… inserting this good tube is important, but can be appropriately delayed and does not need to be rushed. More often, with adrenaline still pumping in *our* veins, the tendency is to advance the drain with a zeal which suggests *their* life depends on it, which may in its own right cause chest drain complications.

4. **Stop:** almost as soon as you have started to advance the chest drain, you also need to **stop** advancing, going only as far as the drain's 4cm marking. This is super important, and so gets more attention below; see 'A good stop'.

A good hole: 4th (or 5th) intercostal space

Choosing the site for thoracostomy and drain insertion can leave many doctors flailing, checking, and second-guessing a good 'site' for this good hole. The 'triangle of safety' is an anatomical zone bounded by the lateral edge of pectoralis major, anterior border of latissimus dorsi, and base of the axilla (which correlates with 5th intercostal space at the level of the nipple; Figure 2). Through this triangle, entry into the pleural cavity is reliably safe. Too low, and the diaphragm, liver or spleen and bowel can all come into the firing line… too high, and the even the axillary vessels can be implicated [7, 8].

Trauma resuscitation rooms are pressurised, hectic and time-constrained environments. Physicians are expected to perform complex, cognitive procedures that command their undivided attention, yet numerous factors conspire to preoccupy and so divert attention. In addition to stress, within the trauma room, environmental factors, such as noise, heat, visual stimuli and motion also can cause distractions that divert attention and lead to errors. Add in to this mix that finding that 1 in 2 junior doctors are unable to recall the anatomy of the 'triangle of safety' when

tested [9], and it is little wonder approximately 40% of chest drains inserted for trauma fall outside of this recommended safe zone [10].

Therefore, when the paediatric patient with critical thoracic injury arrives, **the magic number is FOUR**: 4th (or 5th) intercostal space for safe entry into the pleural cavity. Even counting intercostal spaces can be challenging, and the level is often higher than you may have expected… *but trust the magic* number, and make an incision on the lateral chest wall between the anterior and mid-axillary lines, parallel to the ribs. The length of this incision will vary with the size of the child, and for that matter the instrument (finger, artery forcep or mosquito forcep) you intend to gently push, sweep and keep that good hole, once you've that you've made it.

Remember, once a good hole has been made and the pleural cavity decompressed, the job you came to do is as good as done. Where a therapeutic benefit has been achieved, you can now relax a little with respect to the pending chest drain insertion. As outlined below, inserting the chest drain with misplaced zeal may contribute to iatrogenic complications. In addition, if the child's clinical priorities preclude chest drain insertion at this time, a suitable dressing should be applied in accordance with local protocols to manage the open pneumothorax, e.g. occlusive dressing [11], non-occlusive three-sided dressing [12, 13], or open ended ileostomy bag which acts in the fashion of Heimlich valve. Also, a clear plan must be communicated as to when, where and by whom a chest drain will be inserted when clinical priorities permit.

A good tube: 4 x ETT size

Only those very experienced in paediatric trauma are able to select an appropriately sized chest drain by intuition only, with most choosing a uselessly small or grotesquely large drain. To select a **good tube**, **the magic number is FOUR**: 4 x the size of an uncuffed endotracheal tube (ETT); rounded up to the nearest **4** (French) as this correlates with the typical incremental increase in chest drain sizes (French sizing). Helpfully, the ETT sizing formula (Age/**4** + **4**) is also littered with magic number **4'**s. Drain size is fundamental to the safety and efficacy of your actions as a drain's calibre, length and side hole positions are all related (Table 1). For example, when managing a 2-year-old child, the formula for an uncuffed ETT estimates the ETT sizing to be 2/**4** + **4** = 4.5Fr. Thus, the recommended chest drain calculation becomes **4** x 4.5 = 18, which is then rounded up to 20Fr, as the most commonly used chest drains are supplied in sizes which are multiples of **4**.

A good stop: 4cm

A common pitfall and danger of chest drain insertion in trauma is to advance the drain too far in. This is a predictable error for clinicians who act from the premise that lives are saved by good tubes rather than good holes, and so rush to push (and push and push) the drain into the pleural cavity. A chest drain that is advanced too far can cause significant iatrogenic trauma (e.g. to major vessels at the apex of the pleural cavity or mediastinum, or indeed lung) and/or can kink the tube thus occluding its

lumen and reducing its effectiveness [10, 14]. Less frequently in children, the drain is not effective as it is not advanced enough. Insufficient intra-pleural drain length may be an issue for older or obese children, and is a well-recognised complication of chest drain insertion in adult trauma patients [10, 14].

The morbidity associated with inappropriately sited chest drains can be avoided by knowing when to make a **good stop** to advancing the drain. To inform this stop, **the magic number is FOUR**: advance the tube to the 4cm marking, such that the last drain side hole is 4cm inside the chest cavity. It is important not to misunderstand this instruction to advance the drain into the pleural cavity "by a total length of 4cm". The centimetre markings on a chest drain denote the distance *from the last side hole,* rather than the length to the drain tip or the distance from the skin. Therefore, the length of chest drain within the pleural cavity (i.e. the length from the tip to the 4cm marking) varies with (and is proportional to) the calibre of the drain; Table 1. Thus, if the principles of **good tube** selection are followed, our experience is that length of drain inserted when last side hole is 4cm inside the chest wall reliably ensures the drain position is both safe and effective.

Conclusions

The Rule of 4's provides clinicians of all grades, expertise and distractedness a reliable and pragmatic approach to the injured child who requires safe and effective emergency pleural decompression and timely insertion of a chest drain, through:

1. **4** steps in a **good plan**
2. **4th** (or 5th) intercostal space as the basis for siting a **good hole**;
3. **4** x ETT size (or 4 x [Age/4+4]) to guide selection of a **good tube**;
4. **4cm** mark for a **good stop** to ensure the drain is in far enough *but not too far*.

The utility and benefits of this aide memoire could be further enhanced by adoption of a pre-printed sticker (or electronic medical record equivalent) to be used in conjunction with the procedure [15]. When placed into the patient record, this sticker would clearly outline the steps and key points of *The Rule of 4's,* and ensure the standardised approach being promoted matches that being practiced.

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TABLES

Table 1. Relationship between patient age group vs preferred 'sweeping' instrument, chest drain calibre (size) and length from tip to 4cm mark.

Age group	Suggested 'sweeping' instrument	Uncuffed ETT size[†]	Chest drain size[‡]	Length from drain tip to 4cm mark[§]
0-<2y	Mosquito forcep	3.5-4Fr	16Fr	9cm
2-4y	Mosquito forcep	4.5-5Fr	20Fr	10cm
5-8y	Artery forcep	5.5-6Fr	24Fr	12.5cm
9-12y	Artery forcep	6.5-7Fr	28Fr	14cm
13-16y	Clinician's finger	7.5-8Fr	32Fr	14cm

[†] Uncuffed ETT sizing determined using the formula: Age/4 + 4. [‡] Indicative chest drain sizes are derived from the age-based formula **4x ETT size**, and rounded up to the nearest **4** (French) in accordance with typical chest drain sizing. [§] Length measurements derived from Atrium PVC thoracic catheters, which are in common use in Australasia; exact lengths may vary according to the product used. Ultimately, available drain sizes and pragmatic clinician choices will determine the drain used for a given injured child.

FIGURE LEGENDS

Figure 1. The Rule of 4's

An aide memoire to guide safe and effective decompression of the pleural cavity and insertion of a chest drain in paediatric trauma.

Figure 2. Anatomical landmarks for the 'triangle of safety'

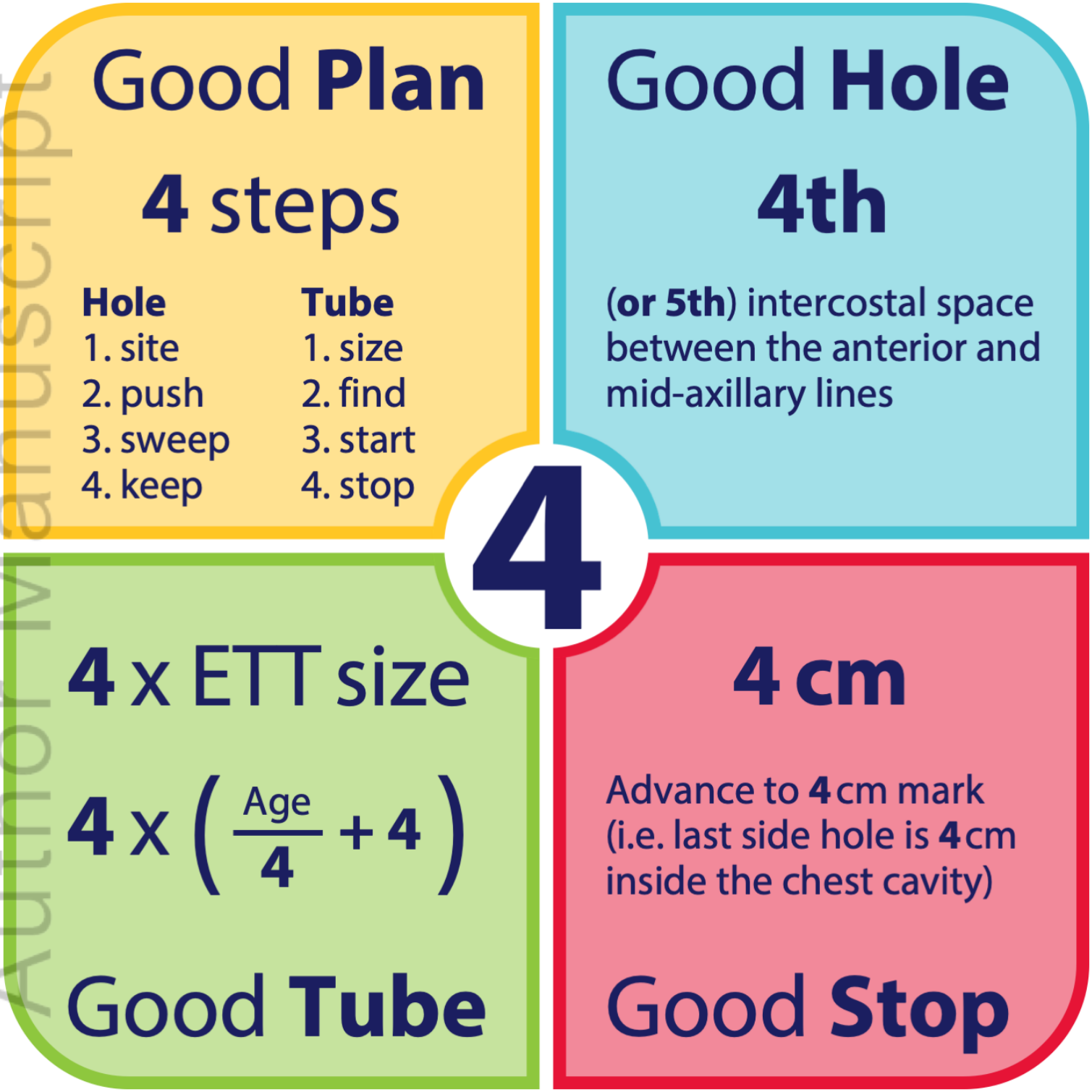
The 'triangle of safety' is bounded by the lateral edge of pectoralis major, anterior border of latissimus dorsi, and base of the axilla (5th intercostal space at the level of the nipple).

Figure 3. Recommended forefinger position when dissecting with a forcep

The proceduralist strategically positions the forefinger of the hand holding the forcep with its tip applied to the hinge mechanism. The benefits of this positioning are twofold: it provides optimal ergonomics for efficient blunt dissection, and provides a physical brake to prevent the forcep jaws plunging unguarded into the chest.

Figure 4. Grasping the chest drain tip when inserting

The suggested technique for grasping the chest drain tip when inserting the drain (**A**) has forceps the grasping either side of the last few centimetres and the tip of the chest drain, and crucially free from all side holes. Avoid the temptation to hook either one (**B**) or both (**C**) forcep jaws through chest drain side, thus cannulating the last few centimetres of the drain with the jaw(s) and exiting through and end hole. Once hooked in, there are often difficulties freeing the forcep jaw(s) from the side hole to advance the drain into the pleural cavity. This introduces avoidable delay and frustration, and worse still may result in the chest drain being dragged back out of the chest if the forcep is withdrawn with chest drain still hooked in and attached.



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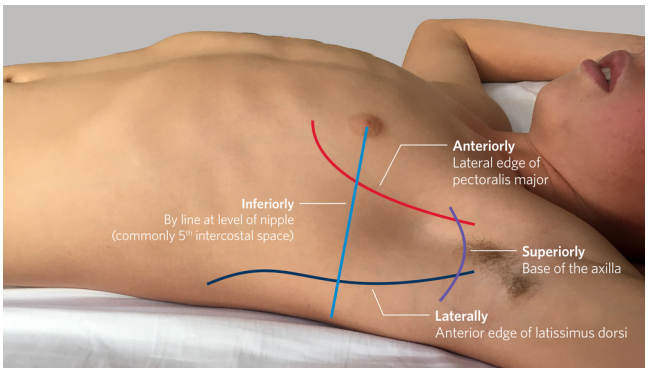

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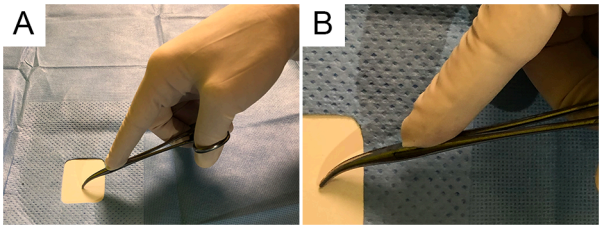

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