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## **Comparison of recognition tools for postoperative pulmonary complications following thoracotomy.**

### **Background:**

The term postoperative pulmonary complication (PPC) encompasses any pulmonary abnormality occurring in the postoperative period producing identifiable disease or dysfunction which is clinically significant. The most frequently seen PPCs following lung resection are atelectasis and pneumonia, with the incidence of PPC (19-59%) much higher than that seen following upper (16-17%) or lower abdominal surgery (0-5%) [1].

Major thoracic surgical procedures may lead to PPC and reduced pulmonary function through atelectasis, secretion retention, altered chest wall mechanics, and abnormal breathing pattern [2]. Thoracic procedures carry a particularly high risk of PPC as surgery directly affects the lungs and associated structures, and patients are generally older and have cardiopulmonary disease associated with smoking, leading to loss of airway elasticity [3]. These procedures are associated with significant complications increasing hospital length of stay (LOS), cost of hospitalisation [4], and need for intensive care unit admission [5]. PPC is the major cause or contributing factor of mortality following lung resection, accounting for up to 84 % of all deaths [5].

Definition of PPC varies widely (hence large variation in reported frequency) and is usually dependent upon a set of criteria which may include such signs as chest x-ray findings, pyrexia and positive sputum microbiology. Various scoring tools have been developed from these type of signs whereby PPC is diagnosed if a certain number of criteria are met. A valid and reliable tool for PPC scoring may be useful for physiotherapists in recognising PPCs amenable to physiotherapy (atelectasis and pneumonia) in thoracic surgical patients.

Physiotherapeutic strategies are thought to be physiologically important in the prevention and treatment of these problems, and a scoring tool may improve communication, prioritisation

and timely intervention in these patients. Although evidence for physiotherapy is limited in this area, there is a small amount suggesting benefit in terms of improving postoperative pulmonary function [6], and incidence of atelectasis [7]. A validated and reliable PPC scoring tool, which could be used for research purposes, would also improve comparability of results. The aim of our study was to evaluate the recognition of PPCs following thoracotomy and lung resection by comparing 3 scoring tools, previously used to assess frequency of PPC in clinical trials, and determine which tool correlates best with clinical outcome.

## **Methods**

### *Design*

A prospective observational study was performed in a regional thoracic centre between October 2007 and April 2008. The study was approved by the clinical governance team of the hospital; ethical approval was not sought or deemed necessary by clinical governance team as this study was purely observational.

### *Patient Selection*

All patients undergoing elective thoracotomy and lung resection were observed prospectively. Demographic data including age, gender, operative procedure, percentage predicted forced expiratory volume in 1 second was collected. Outcomes observed included need for therapeutic bronchoscopy for secretion clearance, antibiotic therapy for respiratory infection, as well as postoperative, high dependency unit (HDU) and intensive care LOS and mortality.

### *Exclusion Criteria*

Emergency surgery, video assisted thoracoscopic procedures, and procedures of the mediastinum and chest wall were excluded.

### *Surgical procedures*

All surgical procedures were performed under general anaesthesia with single lung ventilation. All patients were scheduled for extubation in the recovery room at the end of the operation.

#### *Postoperative Care*

All patients were nursed in a thoracic HDU with pain relief provided either by an epidural infusion, intrathecal morphine and/or intercostal blocks or systemic opioids (parenteral administration or intravenous patient-controlled administration). All patients had an active program of daily postoperative physiotherapy including deep-breathing exercises, incentive spirometry, early mobilisation and sputum clearance techniques.

Antibiotics were commenced when there was clinical and radiological evidence of pulmonary infection and were guided by microbiological advice. Postoperative toilet bronchoscopy was performed when lobar collapse due to sputum plugging did not respond to physiotherapeutic interventions. Patients were readmitted to or had prolonged stay in HDU (or admitted to ICU as appropriate) if they required organ or nursing support.

#### *Assessments of Postoperative Pulmonary Complications*

Assessment of PPC status was performed daily following surgery at midday by the same two independent physiotherapists (P.A. and H.C.) using 3 different sets of PPC scoring criteria, described by Brooks- Brunn [8], Gosselink et al [9], and Reeve et al [10]. For the purposes of this paper we have called these diagnostic scoring tools the Brooks- Brunn score (BBS), Gosselink score (GS) and Melbourne group scale (MGS) respectively. In personal correspondence with individuals who had contributed to its development, it was indicated that the latter tool should be referred to as the Melbourne group scale, not the Reeve score (in order to reflect the group contributions). The BBS was developed to diagnose atelectasis and pneumonia following upper abdominal surgery, the GS ‘clinically significant pulmonary complications’ with ‘infectious variables’ following thoracic surgery, and the MGS PPCs

following thoracotomy and lung resection that are ‘most likely to be prevented by physiotherapy, such as atelectasis and sputum retention, rather than PPCs less amenable to physiotherapy, such as pulmonary oedema and pleural effusion’ [11]. The variables for each scoring tool are shown in Table 1. The BBS and MGS recognise PPC when a certain number of possible set criteria are positive; 2 of the BBS variables positive for 2 consecutive days (it is not stated if these 2 variables have to be the same for the 2 day period), and 4 or more of the 8 MGS variables positive on any day. The GS relies upon all specific criteria being positive (including the chest x-ray score) (Table 1). The thoracic physicians were blinded to the scores so it did not influence treatment given or assessment of chest radiographs . The assessment of criteria for the BBS and GS was performed as described in the papers by Brooks- Brunn [8] and Gosselink et al [9]. Further clarification regarding the GS was needed in order to confirm how microbiology results contribute to the score as it was unclear as described in the paper by Gosselink et al [9]; a positive sputum microbiology report constituted a positive second criteria, even if white cell count (WCC) is negative (personal communication with author), see Table 1. Detailed information/instruction regarding the application of the MGS [11] was used to facilitate its application, and where necessary advice was sought (personal communication with author).

#### *Statistical Analysis*

Continuous variables are expressed as mean ( $\pm$  standard deviation), or median (95% confidence interval) if skewed, and categorical variables are expressed as percentages. Mortality and frequency of intensive care admission were compared with the Fisher’s exact test and postoperative and HDU LOS with the Mann Whitney U test. A p value  $<0.05$  was considered significant.

## **Results**

### *Demographics*

129 consecutive patients were observed; 58% (75) male, mean age 60.9 ( $\pm 15.4$ ) years, mean predicted forced expiratory volume in 1 second 83 ( $\pm 20$ )%.

### *Operative Procedures*

Surgical procedures included pneumonectomy in 12% (15), lobectomy in 50% (64), segmentectomy in 4% (5), wedge resection in 29% (38), exploratory thoracotomy in 3% (4) and sleeve resection in 2% (3) of cases.

### *Score Recognition of PPC*

The incidence of PPC was 6% (8) when scored by the GS, 13% (17) with the MGS and 39% (51) with the BBS. The incidence of PPC in our cohort was 12% (16) as defined by the clinical outcome diagnosis of PPC (clinical or microbiological evidence of pulmonary infection resulting in prescription of antibiotic therapy (15), or clinically significant atelectasis requiring toilet bronchoscopy (1). The MGS correlated best with clinical outcome diagnosis of PPC. All cases of PPC defined by clinical outcome were detected by the MGS and BBS, but only half of cases by the GS. See Table 2 for specificity and sensitivity of the three scores.

### *Length of stay*

There was a significantly longer postoperative length of stay in patients with PPC as recognised by all 3 scoring tools, and significantly longer HDU LOS in those with PPC as recognised by the GS and MGS, supporting the idea that the BBS is over diagnosing and diluting the differences in morbidity as expressed in HDU LOS (Table 3).

### *Mortality*

There were 3 in-hospital deaths in the patient cohort, 2 patients succumbed to postoperative pneumonia, the other myocardial infarction. The GS did not determine PPC in the patients diagnosed with pneumonia, the BBS determined PPC in all of these patients, and the MGS

correctly determined PPC in the 2 patients with the clinical diagnosis of pneumonia only. The MGS demonstrated a significant difference ( $p=.046$ ) in mortality between the group in which it determined PPC (12%) and the group in which it did not determine PPC (1%).

#### *Definition of PPC using the MGS*

It appears that the MGS score of 4 was the appropriate level for this score to determine PPC as no patients with a maximum score of 3 developed a PPC as defined by clinical outcome. Also the median postoperative LOS was significantly lower in patients whose maximum score was 3 versus 4, at 6 (5-7) days compared to 14 (12-19) ( $p<0.001$ ).

#### *Day of PPC manifestation*

Most patients presented with PPC as defined by the MGS with a score  $\geq 4$  during the early postoperative period, with only two manifesting late on postoperative days 10 and 17 (Figure 1). The most commonly positive MGS variables in patients with a score  $\geq 4$  were chest x-ray signs of atelectasis or infiltration (88%), purulent sputum (88%), elevated WCC (88%) and low oxygen saturation (70%). Frequency of the other variables is as follows; physician diagnosis of pneumonia or chest infection 59%, temperature  $>38^{\circ}\text{C}$  47%, positive signs on sputum microbiology 29% and readmission/ prolonged stay intensive care or HDU ( $>36\text{hrs}$ ) 18%. No MGS positive scores were reliant on the variable for administration of antibiotics for pulmonary infection.

## **Discussion**

The incidence of PPC as defined by those treated with antibiotic therapy for respiratory infection or bronchoscopy to clear secretions was 12%. The MGS correlated well with the clinical outcome diagnosis of PPC compared with the BBS, which over diagnosed PPC, and GS which under diagnosed PPC. Scoring positive with the MGS (score  $\geq 4$ ) was associated with prolonged postoperative LOS, HDU LOS and increased mortality.

The BBS criteria, which were developed for the purpose of PPC recognition after upper abdominal surgery, rely on only 2 factors scored positive (for 2 consecutive days), and include new cough or sputum production, altered breath sounds, temperature  $\geq 38^{\circ}\text{C}$ , chest x-ray documentation of atelectasis or new infiltrate, and physician documentation of atelectasis or pneumonia [8]. We tested it in the context of thoracic surgery to determine if it was transferable. However, the BBS may over diagnose PPC in thoracic surgical patients as a significant proportion of them have altered breath sounds due to nature of the surgery, and this was the most frequently positive BBS variable on analysis of our data. Also only 2 criteria are required with this tool for a positive PPC score.

The GS criteria for identification of PPC were developed as an outcome measure for a randomised controlled trial comparing incentive spirometry with standard breathing exercises (n=67) after thoracic and oesophageal surgery. Authors in this negative trial felt there was a low incidence of PPC in lung resection patients (8%) when compared to other published data. However this figure is comparable to the GS PPC frequency in our data, and differs with other published work as PPC definition varies. PPC as determined with the GS may be less than those treated in our cohort because of the stringent inclusion of all 3 criteria for scoring positive, these comprising ‘major’ chest x-ray infiltrates, increased WCC or administration of antibiotic therapy , and temperature  $>38^{\circ}\text{C}$  [9]. The false negative GS PPC scores were either due to chest x-ray scoring, temperature scoring, or a combination of both.

The MGS has recently been used as an outcome measure in a randomised controlled trial (n=76) studying the effect of physiotherapy following thoracotomy and lung resection [11]. It was adapted from PPC diagnostic tools used in similar studies [12,13,14] involving other surgical groups [11]. The incidence of PPC in both limbs of this trial [11] was much lower than anticipated by the authors (4.8% in the treatment group and 2.9% in the control group). The potential explanations for the low PPC rate included possible advancements in analgesia, more emphasis on early postoperative mobility and use of a standardised clinical pathway. This rate is much lower than our current study despite similar demographics, diagnostic criteria and postoperative care pathway. Our results have been consistently reported at this level in a larger group [15].

The MGS has the advantage of not being reliant on radiological findings and does not include altered breath sounds. The categories which were most frequently positive were all objective observations including chest x-ray signs of atelectasis or consolidation, purulent sputum, elevated WCC (>11.2) or administration of respiratory antibiotics, and low oxygen saturation (< 90% on air). Though the MGS has physician diagnosis of pneumonia or chest infection as a scoring factor we found most patients scored in other objective measures and only 1 of the 17 had the contribution of physician diagnosis scoring to become positive for PPC. Each factor is not weighted because this is not designed to be a risk assessment tool but a diagnostic aid.

The ‘modified early warning score’ is a valuable tool used to alert nurses and clinicians of patient deterioration[16]. Similarly the MGS may be a useful, easy to use tool in defining respiratory deterioration in thoracic surgical patients. In our data set 46% of patients who scored 3 with the MGS, went on to score  $\geq 4$ . Whether screening may identify patients at high risk of developing a PPC and whether intervention, such as physiotherapy, can prevent progression in this group is yet to be tested. In addition we have assessed clinical risk factors

for the development of PPC in this group of patients and demonstrated factors associated with PPC, such as age  $\geq 75$  body mass index  $\geq 30$ , American Society of Anaesthesiologists score  $\geq 3$ , COPD and current smoking [15]. Therefore it may be possible to target therapy in a high risk group based on risk factors and the MGS.

The MGS is a simple tool which any physiotherapist, nurse or physician can use since it is based principally on objective measures which are already observed and assessed during the postoperative period. Physiotherapists in our centre collect MGS data routinely on all major thoracic surgical patients, which is available to the multidisciplinary team.

We accept that comparing these scoring tools against the treatment modalities for PPC may miss patients who develop minor PPC, but if not treated these cases may not be of clinical relevance. Patients with chronic lung disease may score false positive. In this study the MGS diagnosed PPC in a patient who did not receive antibiotics or bronchoscopy, but who was a current smoker with chronic obstructive pulmonary disease and sputum retention. The MGS was not designed to detect other pulmonary complications such as broncho pleural fistula or prolonged air leak, but is designed for detecting PPCs amenable to physiotherapy which warrant escalation of physiotherapy treatment and possible mini-tracheostomy and/or flexible bronchoscopy. Also by using a common scoring tool and definition of PPC comparison of research results could be improved.

### **Conclusion:**

Treatment for PPC following thoracotomy is common. Of the three scoring tools, that described by Reeve et al [10] (MGS) best correlates with the clinical outcome diagnosis of PPC described in this paper. Patients with a PPC positive MGS have a worse outcome as defined by mortality, HDU and postoperative length of stay. The MGS is an easy to use

multidisciplinary scoring tool, but further work into its use in minimally invasive surgery and in targeting high risk groups for therapy is required.

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This study was undertaken as part of an observational departmental audit of postoperative pulmonary complications, approval was granted by the clinical governance department for the collection of this data. We declare no conflict of interest.

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**Table 1: PPC scoring criteria as described by Reeve et al [10], Gosselink et al [9] , and Brooks-Brunn [8]**

MGS- Reeve et al [10]	GS- Gosselink et al [9]	BBS- Brooks-Brunn [8]
Temperature $>38^{\circ}\text{C}$	Temperature $>38^{\circ}\text{C}$	Temperature $\geq 38^{\circ}\text{C}$
WCC $>11.2$ or respiratory antibiotics	WCC $>12$ (or positive microbiology)	
Physician diagnosis of pneumonia or chest infection		Physician documentation atelectasis/pneumonia
Chest x-ray report of atelectasis/consolidation	Chest x-ray Score 0-no abnormality 1-minor unilateral atelectasis 2- minor bilateral atelectasis 3- major unilateral atelectasis or infiltration 4- major bilateral atelectasis or infiltration	Chest x-ray documentation of atelectasis /new infiltration
Production of purulent (yellow/green) sputum differing from preoperative		New Cough / Sputum
+ve signs on sputum microbiology		
SpO $_2 < 90\%$ on room air		
Readmission to or prolonged stay (over 36 hours) on the intensive care unit/HDU for respiratory problems		
		Abnormal Breath sounds compared to baseline
<b>PPC = 4 or more positive variables</b>	<b>PPC = Chest x-ray score of 3 or 4 and positive in other 2 variables</b>	<b>PPC = 2 variables positive for two consecutive days</b>

**MGS- Melbourne group scale [10]**

**GS- Gosselink score [9]**

**BBS- Brooks-Brunn score [8]**

**Table 2: Specificity and sensitivity of the three scores.**

Score	Specificity	Sensitivity
MGS- Reeve et al [10]	99%	100%
GS- Gosselink et al [9]	100%	50%
BBS- Brooks-Brunn [8]	69%	100%

**Table 3: Postoperative and HDU LOS for PPC and Non PPC patients (as determined with each scoring tool)**

<b>Score</b>	<b>Median (95%CI) postoperative LOS (days)</b>			<b>Median (95%CI) HDU LOS (days)</b>		
	PPC	Non- PPC	p value	PPC	Non- PPC	p value
<b>GS [9]</b>	17(10-22)	5 (5.5-7)	<0.001	4 (2-9)	1 (1.7-2.3)	0.002
<b>MGS[10]</b>	12 (11-18)	5 (5-6)	<0.001	5 (3-7)	1 (1.5-2)	<0.001
<b>BBS [8]</b>	7 (7-10)	5 (5-6)	0.001	2 (2-3.5)	1 (1.5-2)	0.187

**GS- Gosselink score [9]**

**MGS- Melbourne group scale [10]**

**BBS- Brooks-Brunn score [8]**

**Figure 1:** The timing of presentation of patients first scoring  $\geq 4$  with the Melbourne group scale in the postoperative course.

