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# Patients after lung resection heading to the high-dependency unit: a cost-effectiveness study for managing lung cancer patients

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## Abstract

**Background:** Recently, most thoracic surgery units allocate patients post lung resection to high-dependency units (HDU) rather than the old trend of intensive care units (ITU). The aim of the study is to assess the safety and efficacy of such a policy. We compared a single group of patients who underwent lobectomies who were admitted to ITU before March 2011 and patients whom their destination was to HDU after that date. Preoperative factors and postoperative outcomes were compared.

**Results:** A total of 408 patients were studied, 203 post-lobectomy patients were admitted routinely to ITU before March 2011, while 205 patients were admitted to HDU after that date. The mean postoperative length of stay in ITU was 1.2 days while in HDU was 1.1 days. In-hospital mortality for the ITU group was 2.5% ( $n = 5$ ) while in the HDU group was 1.4% ( $n = 3$ ) ( $p = 0.43$ ). ITU readmission was observed in 6.5% ( $n = 13$ ) in the ITU group and 4.3% ( $n = 9$ ) in the HDU group ( $p = 0.31$ ). Total complications were present in 39% in the ITU group and 33% in the HDU group ( $p = 0.16$ ). The total estimated cost of one ITU day per patient is 850 GBP in comparison with 430 GBP for the HDU group ( $p = 0.007$ ). The incremental cost-effectiveness ratio of the HDU stay per year was US \$32.130/QALY.

**Conclusion:** The high-dependency unit is a safe destination for post-lobectomy patients. The same concept may apply to all thoracotomy patients. Hospitals could adopt such a policy which offers a better financial option without jeopardizing the level of patient care or outcome.

**Keywords:** High-dependency unit, Cost-effectiveness, Lung cancer, Lobectomy

## Background

Postoperative surgical patients require different levels of care depending on preoperative conditions and operative complications. This is usually anticipated preoperatively and is reassessed in the operating theatre, and the recovery rooms and decisions should have been planned for

the next level of care or subsequently according to the clinical dependency postoperatively.

The ability to recognize and optimize the care of postoperative patients is vital and the key success in the outcome of all surgical procedures including thoracic surgery patients [1]. This fact was recognized long ago, since the establishment of the “Nightingale” ward, where patients were close to the nursing station. With advances in technology and medical awareness, the intensive therapy unit (ITU) was created nearly five decades ago for monitoring, treating, and providing mechanical

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ventilation and has always shown superiority in managing critically ill patient at the expense of higher medical costs [2].

Inappropriate use of these units has drawn attention and questioning. Many studies have proven the inappropriateness in ITU as a destination while the patients could have been managed in closely monitored areas. The recognition of the above problem has led to the development of an intermediate care or high-dependency unit (HDU) which showed to be of great value to surgical patients [3, 4]. The Association of Anaesthetists of Great Britain and Ireland defined HDU as “an area for patients who require more intensive observations, treatment and nursing care than can be provided on a general ward provided that those patients are not mechanically ventilated” [5].

There are 36 units in the United Kingdom (UK) that perform lung resections, and our unit comprises 10% of the thoracic load in the UK. Recently, most thoracic surgery units allocate patients post lung resection to HDU rather than the old trend to ITU. To our knowledge, there has not been any study assessing the safety and efficacy of such a policy in comparing solely lobectomies destined to HDU and whether HDU is the safe destination compared to ITU and the cost-effectiveness of such policy. Therefore, we found it was prudent to proceed and investigate performing such a study which was performed in one specialized centre.

## Methods

The policy in our institution since March 2011 was to admit post-thoracotomy patients to HDU. We compared a single group of patients who underwent lobectomies for lung cancer and were admitted routinely to ITU from March 2005 until March 2011 to those whom their destination was HDU from March 2011 to 2018.

Preoperative factors studied included demographics, cancer staging, and pulmonary function test. Postoperative outcomes included ITU/HDU stay, major postoperative complications, and mortality.

Intraoperatively, patients had a posterolateral thoracotomy through the fourth/fifth intercostal space, targeted lobectomy, and regional pain control through an epidural catheter analgesia or paravertebral catheter according to surgeon/anaesthetist preference.

Postoperative complications recorded included prolonged air leak, renal dysfunction, perioperative myocardial infarction, atrial fibrillation, pulmonary complications (infection/collapse), wound infection, neurological complications (cerebrovascular stroke/transient ischemic attack TIA), gastrointestinal bleeding, and ITU/HDU psychosis.

Data was collected and recorded from the hospital database. Comparison of the cost was estimated for both groups by comparing the estimated total cost of a single ITU day versus the total cost of a single day spent in the HDU.

The HDU at our institution is composed of six beds with a nurse-to-patient ratio of 1:2, while the nurse-to-patient ratio in the ITU is 1:1. The HDU nurses are trained to run HDU units and have excellent clinical experience from ITU training. The unit is located within the thoracic ward and separate from ITU, where all the staff are trained to manage cardiothoracic patients. Standard HDU equipment is available. There is close liaison between the surgeons, nurses, anaesthetists, intensive care team, pain specialist nurses, and chest physiotherapists.

The decision to admit post-thoracotomy patients to the ITU was a routine during our study period from March 2005 to March 2011. The decision to allocate patients to the HDU or ITU after that date was a joint decision between the anaesthetist, intensivist, surgeon, and critical care nurse coordinator. Patients undergoing a thoracotomy for any thoracic procedure and not requiring postoperative mechanical ventilation and not requiring care for more than one organ system were considered candidates needing a higher than ward level of care but not requiring an intensive care unit. Patients stepping down from the ITU to the ward and patients stepping up from the ward and requiring not more than one organ system support with no need for mechanical ventilation were again considered candidates for HDU admission. The requirement for mechanical ventilation or more than one organ system support was considered a contraindication for HDU admission and was transferred directly to the ITU. This group of patients were excluded from the study as their ITU requirement was not based on performing the surgical procedure only but due to other comorbidities.

All methods were carried out in accordance with relevant guidelines and regulations. Ethical committee (EC) approval from the EC department was registered under no. 2018/RET-ASU/37. Participant confidentiality and data security were guaranteed. The requirement for patient consent was waived through the EC advise.

Costs were collected from our finance department. Cost-effectiveness was calculated using the incremental cost-effectiveness ratio (ICER) using the quality-adjusted life year gain \$/QALY [6]. Statistical methods involved in carrying out this study included planning, designing, collecting data, analysing, drawing meaningful interpretation, and reporting of the research findings. A retrospective propensity matching score using bipartite analysis with matching ratio of 1:1 and matching

algorithm of greedy matching was used. A Hosmer-Lemeshow goodness of fit test was used. The collected data was revised, coded, tabulated, and introduced to the PC using Statistical Package for Social Science SPSS V20 (SPSS Inc., Chicago, IL). Data was analysed using student paired *t*-test and exact Fisher test. Data was presented as median with range and numbers (percentages), as indicated. A *p*-value of less than 0.05 was considered significant.

**Results**

A propensity-matched score was performed to allocate patients with no significant difference in demographics, preoperative respiratory, and cardiac dysfunction between both groups. The procedure was standardized as an open lobectomy to treat lung cancer. Two-hundred and three lobectomy patients for lung cancer were admitted to ITU before March 2011, while 205 patients were admitted to HDU after that date for the same procedure.

Male patients in the ITU group were 62% in comparison with 64% in the HDU group (*p* = 0.82). The median age for the ITU group was 70 years, while the median age for the HDU group was 69 (*p* = 0.8). The median body mass index for the ITU group was 25.5, while for the HDU group, it was 25 (*p* = 0.92). The median FEV1 as a percent of predicted was 82.8% for ITU and 83.1% for the HDU group (*p* = 0.91). History of myocardial infarction was 14% (*n* = 29) in the ITU group, while in the HDU group, it was 11% (*n* = 23) (*p* = 0.28).

The postoperative nodal status as a marker of disease stage is shown in Table 1 and shows no statistical significance (*p* = 0.07).

**Table 1** Postoperative nodal state comparison between both ITU and HDU groups

Stage/ group	N0	N1	N2	Total	Significance
ITU	146 (72%)	41 (20%)	16 (8%)	203	<i>P</i> = 0.078
HDU	161 (78.5%)	34 (16.5%)	10 (5%)	205	

The mean postoperative length of stay in ITU was 1.2 days while in HDU was 1.1 days (*p* = 0.9). In hospital mortality for the ITU group was 2.5% (*n* = 5) while in the HDU group was 1.5% (*n* = 3) (*p* = 0.43). Causes of mortality were respiratory failure, sepsis, multiorgan failure, myocardial infarction, and pulmonary embolism.

ITU readmission was observed in 6.9% (*n* = 14) in the ITU group and 9.6% (*n* = 20) in the HDU group (*p* = 0.19). Of the 20 patients readmitted after HDU discharge, 11 were admitted to the ITU and 9 readmitted to the HDU. Total complications were present in 39% (*n* = 79) in the ITU group and 33% (*n* = 68) in the HDU group (*p* = 0.16). The total estimated cost of one ITU day per patient is 850 GBP in comparison with 430 GBP for the HDU group (*p* = 0.007). The incremental cost-effectiveness ratio of the HDU stay per year was US \$32.130/QALY (calculated by difference in cost multiplied by mean ITU stay for patients per year).

A comparison of postoperative outcomes between both groups is shown in Table 2.

**Discussion**

The financial burden facing medical institutions of inappropriately destined patients to the intensive care unit has raised concerns and encouraged the search for an alternative destination to those patients requiring intensive observations and nursing. This issue was addressed and has led to the development of high-dependency units (HDUs) [7].

A previous study has suggested that HDU could be a safe destination in thoracic surgery patients [8], but the study included all thoracic procedures including esophagectomies and was performed in two centres with two different policies. Our study was designed to compare one specific surgery, and that was patients undergoing open lobectomies for lung cancer.

The HDU should be a balance between reducing unnecessary costs of transferring noncritically ill patients from the ITU to the more cost-effective HDU and upgrading the care of patients who required more attention from being transferred to the ward. Our study has compared

**Table 2** Comparison of postoperative outcomes between both groups

Outcome	ITU group ( <i>n</i> = 203)	HDU group ( <i>n</i> = 205)	Significance ( <i>p</i> -value)
ITU/HDU stay	1.2 days	1.1 days	0.90
ITU/HDU readmission	6.9% ( <i>n</i> = 14)	9.6% ( <i>n</i> = 20)	0.19
Mortality	2.5% ( <i>n</i> = 5)	1.5% ( <i>n</i> = 3)	0.43
Total complications	39% ( <i>n</i> = 79)	33% ( <i>n</i> = 68)	0.16
Cost per day	850 GBP	430 GBP	0.007

a specialized ITU to a dedicated HDU, both in a tertiary cardiothoracic centre.

Many postoperative deaths occurred in those patients who returned to the ward immediately postoperatively and could have been prevented if an HDU was those unfortunate patients destination [9]. This was previously supported by another report by Gamil and his colleagues where they concluded that 17% of postoperative complications would have been prevented by the existence of a HDU [10].

The critically ill surgical patient accounts for 60–70% of the workload of the general intensive care units (ICUs) in the UK, and there is a recognized shortage in allocating resources towards the development and improvement in HDUs in this country, despite repeated national audits urging that this resource be increased [11]. As proven by our study, HDU is a safe destination for lung resection surgery, and we encourage this policy and hope more thoracic units invest in such a policy.

The efficacy of transferring postoperative high-risk surgical patients to the HDU and challenging their need for an ITU has been studied in other non-thoracic specialties.

A study by Betten et al. [12] looked at 62 patients who underwent major colorectal surgery and were transferred to an HDU rather than an ITU. They found that most patients needed HDU-specific interventions during the first 6 h of the postoperative period only. After this, one-third of the patients needed one or more of the HDU-specific interventions for shorter periods of time. Another one-third of the patients had a need for HDU-specific therapies for more than ten consecutive hours, primarily an infusion of norepinephrine. This showed the HDU to be even more than needed care for patients after GIT resections.

A study from Aberdeen looking at 128 patients who had airway surgery in the otolaryngology unit concluded that the care provided in the HDU prevented the need for escalation of care to an intensive care unit. The authors suggested that this challenges the need for patient management on intensive care units following major surgery or airway compromise for those not requiring assisted ventilation [13].

A study by Angel et al. [14] looked at postoperative care in patients having undergone carotid endarterectomies. They suggested that a careful selection of patients preoperatively could lead to a reduction in the number of ITU admissions in a safe and cost-effective manner with patients instead going to the HDU.

A thoracotomy incision can sometimes be considered a pathology which hinders adequate respiratory mechanics and is labelled as one of the most painful incisions [15]. Pain management is crucial after a thoracotomy incision, and the policy in our department started mainly with

routine insertion of an epidural catheter analgesia and has shifted to intraoperative insertion of paravertebral catheter analgesia in the last decade due to the findings of shorter hospital stay and less side effects of narcotics [16, 17]. Requirement of respiratory support, pain management, and close monitoring of dynamics after a lobectomy has encouraged most thoracic surgery units to allocate postoperative patients to a level of care superior to a general ward. HDU is an ideal location for this. We are one of the leading video-assisted thoracoscopic VATS units and believe that minimally invasive techniques can avoid the hazards of a thoracotomy, but we have chosen to study only the thoracotomy patients in this study to avoid confounding, and we still believe that a thoracotomy is always required in a subset of patients and is probably still the most common thoracic surgical incision in the world.

The role of our HDU in a busy cardiothoracic tertiary centre is to serve three main purposes in moving patients from different levels of care. The first purpose is being the main destination for postoperative thoracotomy patients in the thoracic department, provided the patient does not require mechanical ventilation.

Secondly, patients may often be defined as a “step-down” by confirming that they no longer meet any criteria for requiring full intensive care but may still require frequent monitoring and/or nursing care and may also have some minimal organ support requirements. Examples are mechanically ventilated post-thoracic surgery patients who are now off ventilation and require some respiratory support. Another example is a post-cardiac surgery patient with a heart block awaiting pacemaker insertion. Patients who are critically ill rarely achieve transition directly from full intensive care to ward-level care. This step-down policy has been shown to improve patient outcomes [18].

Finally, the last group is the “step-up” patients who are admitted to the HDU from a regular ward with increased care requirements. This group of patients generally includes those with acute clinical changes after cardiothoracic surgery, such as those with acute/subacute respiratory compromise requiring noninvasive ventilatory support or those requiring acute renal replacement therapy. This could constitute a significant group of patients and has shown in a study to form more than half of the patients admitted in the HDU [19], but the proportion is different in our unit as post-thoracic surgery patients form the main population of patients visiting the HDU.

As a busy cardiothoracic unit, there is a huge load on the ITU from the cardiac surgery side. The availability of HDU has solved an enormous problem in freeing ITU beds for the cardiac side reduced unnecessary ITU admissions. We have also been able to recruit ITU

nursing staff to train new HDU nurses in a more comfortable training zone than the ITU. This has allowed us to have a wide nursing cover for our HDU. This efficacy in nursing staff training opportunity has been shown in another study [8]. HDU has been cost-effective without compromising patient safety but in fact improved postoperative outcomes. Our financial saving from investing in HDU has proven to save us nearly half of the cost of admission to the ITU (850 pounds/day/patient vs 430 pounds/day/patient). This is similar to a cost estimated in a similar study which has estimated that the cost of treatment in ITU is 800 pounds a day, while that would be 440 pounds a day for an HDU bed [20]. This significant difference in cost is primarily due to the nursing costs/salaries in the ITU compared to HDU due to the differences in patient-to-nurse ratio in addition to different equipment costs.

As evident from this study, investing in a cardiothoracic HDU has helped to optimize patient care through maintaining the quality of critical care needs, freeing ITU beds, allowing proper training of nursing staff, earlier patient discharge, and, importantly, being cost-effective.

Although we have studied a single postoperative factor that affects outcome, we believe that this is just one of many. The modern preoperative assessment and optimization methods, the extent of the resection, the surgical techniques including minimal invasive techniques (there is a growing evidence that immediate postoperative care in a general ward after minimal invasive lobectomy for lung cancer is safe and feasible without deteriorate outcomes), and both hospital volume and surgeon volume (higher hospital and surgeon volume are clearly associated with reduced postoperative mortality in complex procedures), among others factors, are at least equally relevant to the postoperative care.

There are few limitations in our study. This is a retrospective review but carries many patients studied, and it would be currently difficult to randomize patients to different postoperative destinations. We have limited the study to one procedure to prevent confounding, although it may be argued that this may be difficult to apply for all thoracic surgery procedures.

## Conclusions

The high-dependency unit (HDU) is a safe destination for post-lobectomy patients. The same concept may apply to most post-thoracic surgery patients. Hospitals could adopt such a policy which offers a better financial option and possibly a better training opportunity for nursing staff without jeopardizing the level of patient care or outcome.

## Abbreviations

HDU: High-dependency unit; ITU: Intensive therapy unit; UK: United Kingdom; VATS: Video-assisted thoracoscopic surgery; GIT: Gastrointestinal tract.

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None

## Authors' contributions

HHE conceived the study, which was overseen by MG. All authors were involved in the development of the methodological approach. HHE wrote the article, which was reviewed and revised by all authors. The authors read and approved the final manuscript.

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## Availability of data and materials

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## Declarations

### Ethics approval and consent to participate

Not applicable

### Consent for publication

Not applicable

### Competing interests

The authors declare that they have no competing interests.

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