ISSN 2345-1210 | Volume 10

Japanese Journal of Gastroenterology and Hepatology

Research Open Access

Prevention of Post-Operative Pneumonia Following Emergency Laparotomy: A Review

NX Ho*, A Mehanna and V Bhattacharya

Department of General Surgery, Queen Elizabeth Hospital, Gateshead Health NHS Foundation Trust, Gateshead NE9 6SX, United Kingdom

***Corresponding Author:**
Ning Xuan Ho,Department of General Surgery, Queen Elizabeth Hospital, Gateshead Health NHS Foundation Trust, Gateshead NE9 6SX, United Kingdom

Received: 24 Apr 2025
Accepted: 02 May 2025
Published: 06 May 2025
J Short Name: JJGH

Keywords: Emergency Laparotomy; Emergency General Surgery; Post-Operative Respiratory Complications; Care Bundles; Management; Prevention

Citation: NX Ho. Prevention of Post-Operative Pneumonia Following Emergency Laparotomy: A Review. J Gastro Hepato. 2025; V10(14): 1-5

1. Abstract

1.1. Background and Aims

Emergency laparotomy is an expensive and commonly performed emergency surgery that is associated with high mortality and morbidity. Post-operative respiratory complications, such as post-operative pneumonia (POP) is a common morbidity following emergency laparotomy. POP is associated with high cost and challenging treatment options. This article aims to review and highlight the risk factors of POP identified in current literature and the latest management strategies for POP.

1.2. Methods and Results

A literature search was conducted on PubMed®, using the key words "emergency laparotomy", "prevention of post-operative pneumonia and "post-operative respiratory care bundles". A local departmental audit was performed to assess our centre's current practices and against standards set by current evidence and preventative strategies for POP. Current preventative strategies for POP focusses on improving oral care, chest physiotherapy, regular coughs and deep breathing exercises, and the use of incentive spirometry. Care bundles such as I-COUGH have been shown to be successful in the reduction of POP when implemented.

1.3. Conclusions

Post-operative respiratory complications such as POP represents a significant element of morbidity and mortality following emergency laparotomy. Bundled standardised post-operative respiratory care pathways in combination with appropriate nursing education is essential for successful implementation of a care bundle.

2. Background and Introduction

Emergency laparotomy is an acute abdominal surgery associated with high costs and high mortality in acute hospitals. Between December 2020-November 2021, 22 132 emergency laparotomies were performed in the United Kingdom [1]. It is a common yet diverse procedure carried out by the emergency general surgery team, described as an intrabdominal exploratory procedure where the clinical presentation, underlying pathology, anatomical site of surgery and perioperative management can vary considerably between each procedure [2]. The variation in surgical pathology, patient physiology at the time of presentation, increasing elderly population, coupled with the nature of emergency caseload and limited time for preoperative optimisation of the patient, contributes to the high incidences of postoperative morbidity and mortality. In 2013, Murray et al established the National Emergency Laparotomy Audit (NELA) within the UK Emergency Laparotomy Network, where 173 acute hospitals across England and Wales submitted data on emergency laparotomy. In its eighth year running, in-hospital mortality was found to be 9.2% in the 2020-2021 audit year [1]. There is a clear association between rising age and 30-day mortality following an emergency laparotomy, with an risk increment of 4% every 10 years from the age of 50. Other than patient age and co-morbidities, post-operative pneumonia (POP) is a common complication in post-operative patients - leading to morbidity, mortality and increased cost of care. Postoperative pneumonia is defined as a hospital acquired pneumonia developing 48-72 hours after admission in a post-surgical patient [4,5]. A recent study by Howes and colleagues have demonstrated that pulmonary-related complication was the second most common category of post-operative morbidity following emergency laparotomy, with a reported incidence of 71.5% of a 114 patient cohort (6). Pneumonia has significant relevance as it can negatively affect patient safety and the outcomes of their surgeries. It has shown to increase mortality and morbidity in patients. Mortality can range from 20-50% and studies have shown to affects late quality of life (7). There is also a financial burden on the NHS with patients having their stay in hospitals increased by 7-9 days, with hospital acquired infections costing the NHS up to an estimated £2.7 billion (8). The annual estimated cost of approximately £650 million can be attributed to emergency laparotomy in England [9]. Post-operative pneumonia (POP) in the surgical patient is largely multifactorial, and represents a known complication in general surgical patients, with reported incidences ranging from 0.5% to 28% (6). In critically ill patients who have had an emergency laparotomy, impaired host defences and the increased risk of aspiration of gastrointestinal tract contents represent some of the more common cause of post- operative pneumonia [5,6]. The pathogens involved in POP is largely polymicrobial in nature, and with the increasing antimicrobial resistance crisis, treatment is becoming increasingly challenging [10]. Therefore, there is a need to identify preventable risk factors and utilise care bundles for post-operative respiratory care to reduce the incidences of POP. We aim to review and highlight the risk factors of POP identified in current literature and the latest management strategies for POP.The I COUGH program showed success where incidence of postoperative pneumonia reduced from 2.6% to 1.6% within a year of implementation [11]. We aim to use the same in our hospital in particular, our emergency laparotomy patients in the General Surgery department where we have roughly 60-100 cases a year. While pneumonia can be a clinical diagnosis, we shall use radiological changes for our definition of pneumonia.

3. Methods

3.1. Literature Search

An electronic literature search was conducted on PubMed®, using the key words "emergency laparotomy", "prevention of post-operative pneumonia, and "post-operative respiratory care bundles", to review current evidences and strategies in the management of

post-operative pneumonia following emergency laparotomy. The search was limited to articles published in English language only. The search yielded 11 articles detailing post-operative pneumonia preventative bundles, however none were specific to emergency laparotomy patient cohorts. Selected articles are detailed in our references, are explored and summarised in this review article.A local departmental audit was also carried out concurrently to review our own practices in the General Surgery department in Queen Elizabeth Hospital, Gateshead. This was performed to audit our standards of practice within the department and set a baseline prior to introducing a reformed prevention of post-operative pneumonia bundle at our centre.

3.2. Local Departmental Audit

We carried out a retrospective audit on the incidences of POP at our centre, with an aim to evaluate its association with mortality following emergency laparotomy. Data were collected and analysed retrospectively from patients who underwent emergency laparotomy between January 2019 December 2022. This data was available through our local electronic NELA database. A total of 65 patient mortality post emergency laparotomy were identified at our centre. Patient demographics, cause and date of death were further reviewed and collated through local electronic and paper medical records to delineate the incidences of POP and associated mortality at our centre. We used Microsoft Excel for statistical analysis of the data. Following basic statistical analysis, the main causes of mortality following emergency laparotomy at our centre (Figure 1) were identified as POP (18 patients, 28%), multiorgan failure (16 patients, 25%), peritonitis (8 patients, 12%) and others (23 patients, 35%). Our centre's incidence of POP aligns with current reported incidences of POP in general surgical patients as detailed above [5-7].The mean age of the patients was 74.3 years with a range of 44 years (Figure 2). Figure 3 demonstrates the mortality after emergency laparotomy is similar in both genders but mortality from POP was higher in the male group (68.40 % Vs 31.60%). Incidences of mortality from POP were audited against current our Trust's practices on post-operative feeding and utilisation of prevention of post-operative pneumonia (POPP) protocols. The mean duration between post-operative time and initial post-operative feeding for patients who developed POP were 2.88 days via nasogastric/nasojejunal routes and 4 days via oral route. Following review of local compliance with POPP protocol, we found that only 53% of the patients who had developed POP had a POPP protocol prescribed.Our audit has highlighted that POP remains a significant risk factor to mortality in patients who underwent emergency laparotomy. More importantly, there is need to reinforce the utilisation of- and rigorous education surrounding local POPP protocols. To improve our centre's POPP pathway, and subsequent patient outcomes, we have conducted a review on current evidence-based POPP strategies whilst identifying important risk factors of POP. We hope to introduce and implement a reformed POPP bundle at our centre, based on up-to-date evidences in current literature. Following implementation of this new POPP bundle, we will complete the audit cycle by completing a re-audit to assess future patient outcomes.

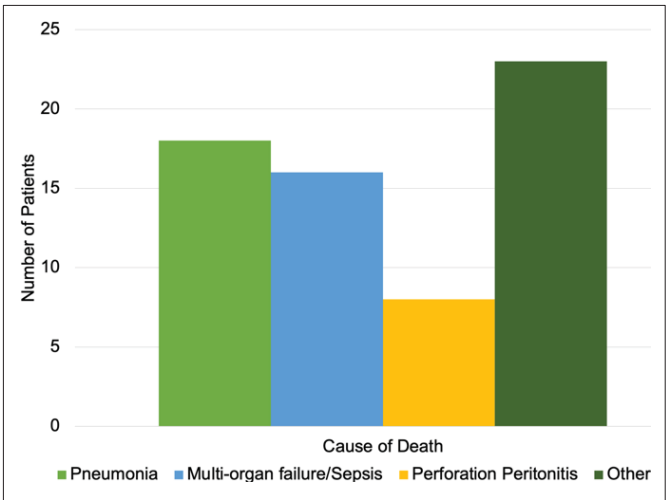

Figure 1:Graphical representation of the main causes of mortality from our local departmental audit.

4. Risk Factors

4.1. Pre-Operative

4.1.1. Chronic Obstructive Pulmonary Disease (COPD)

Chronic obstructive pulmonary disease (COPD) is growing pandemic with the global health crisis of smoking in the modern era. COPD is characterized by persistent airflow limitation and ventilatory restriction, and is associated with increased morbidity and mortality [12,13]. It has been established by various reports that moderate-to-severe COPD is an independent risk factor for post-operative respiratory complications after abdominal surgery [14-17].

4.2. Smoking

Chronic inflammation of the lungs is prevalent in current smokers, in addition to a high prevalence of abnormality of dynamic compliance, closing volume, maximal mid-expiratory flow, and residual volume [18]. As a result of smoking, there is progressive deterioration of pulmonary functional reserve and a reduced pulmonary function in current active smokers [19]. Unsurprisingly, smoking has been identified as an independent risk factor for the development of post-operative respiratory complications [17].

4.3. Intra-Operative

4.3.1. Operative Time

Several studies have shown that a prolonged operative time and anaesthesia of more than 3 hours were risk factors for the development

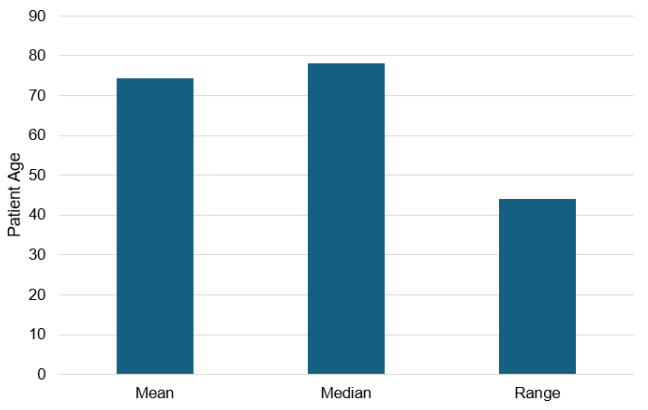

Figure 2: Age distribution of patient cohort, from our local departmental audit.

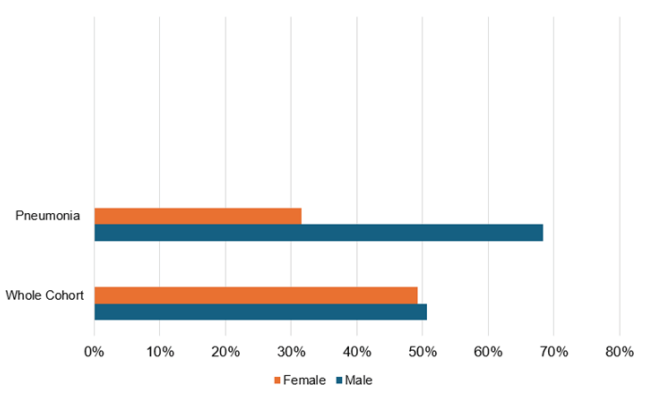

Figure 3: Local departmental audit findings of post-operative mortality following emergency laparotomy, subcategorised by gender.

of post-operative pneumonia and other respiratory complications [20-23]. Whilst under general anaesthesia and in a supine position intra-operatively, there is a direct consequence to patient's lung volume, as it becomes restricted and subsequent impaired gas exchange capacity during surgery [24]. As a result, this leads to impaired lung compliance and a risk to developing post-operative pulmonary complications. Due to the vast variability of surgical pathology involved in thean emergency laparotomy, operative time is highly variable and could last longer than 3 hours in cases of complex anatomy, severe adhesions and/or when complex bowel resection is needed.

4.3.2. Urgency of Surgery-Emergency Surgery

Compared to elective abdominal surgery, patients presenting with an acute abdomen necessitating immediate surgical intervention are often one the sickest in the hospital and often do not have the luxury of dedicated pre-operative optimisation, given the urgency of the surgery required. Many studies have identified emergency surgery as an independent risk factor for the development of pulmonary complications post-operatively [14,25-27]. The combined stressors of the pathophysiological insult from an acute abdomen and surgery pose a risk for cardiopulmonary dysregulation and complications post-operatively.

5. Post-Operative

5.1. Critical Care Admission

Critically ill patients have a high risk of aspiration and aspiration pneumonia, largely due to their supine position, gastroparesis and nasogastric intubation [28-30]. Additionally, patients who have been intubated and placed under sedation are known to have an altered swallowing reflex, even in patients who have been intubated for as short a time as 24 hours [31,32]. Majority of surgical patients post-emergency laparotomy are admitted to the intensive care unit post-operatively and are susceptible to the aforementioned risks of developing post-operative pneumonia.

5.2. Post-Operative Ileus

Patients who have had bowel surgery are at a risk of post-operative ileus (POI), which can be defined as a physiological arrest to gastrointestinal transit in response to surgical stress [33]. More often than not, patients who have undergone an emergency laparotomy would have had a degree of intestinal manipulation, due to the nature of pathologies indicated for an emergency laparotomy [1,3]. Coupled with the regular administration of opioids and sedatives post-operatively, POI can be attributed to multiple reasons, all of which can be applied in post-emergency laparotomy patient. POI leads to nausea and vomiting, abdominal distension, delayed gastric emptying, all of which pose a risk of aspiration pneumonia in any cohort of patients who have had abdominal surgery [34,35].

5.3. Role of Post-Operative Respiratory Care

Post-operative respiratory complications, including pneumonia (POP) is common and associated with high healthcare expenditure. The costs associated with post-operative respiratory complications have been shown to be over USD$52,000 per patient in the United States [36]. With the increased length of stay and associated high costs, it is important for clinicians to understand the role of post-operative respiratory care and utilise it effectively to prevent problematic post-operative respiratory complications. As detailed above in the risk factors section, the overall combined impact of surgical trauma and anaesthesia results in reduced pulmonary function and consequently inevitable atelectasis. As a result of atelectasis post-operatively, hypoxaemia and translocation of microbes into the systemic circulation can lead to pneumonia and increased patient morbidity and mortality [37,38]. Furthermore, patient positioning, administration of strong opioid analgesics can restrict and worsen lung volumes, leading to significant reduction in the functional residual capacity and vital capacity [39]. Post-operative respiratory care focuses on techniques and interventions that increase lung volumes and improve coughing mechanisms post-operatively, with the aim of counteracting the negative impacts of atelectasis. Many of these techniques are low cost and easy to employ in the post-operative setting. Examples of post-operative respiratory care include, coughing and deep breathing, incentive spirometry, chest physiotherapy, regular mobilisation and oral care [39-42].

5.4. Oral Care

In recent years, clinicians have identified poor oral hygiene as a contributory factor to POP [40]. It is thought that one of the main causes of postoperative pneumonia is aspiration of saliva containing pathogenic microorganisms, leading to bacterial translocation and subsequent chest infection. Investigators have since introduced interventions to improve perioperative oral care, such as oral health instruction, dental scaling, removal of tongue coating, denture cleaning, instructions for gargling and regular teeth-brushing, to prevent post-operative pulmonary complications secondary to aspiration40. Akutsu and colleagues have found that by instructing patients to brushing their teeth five times per day decreased the frequency of postoperative pneumonia from 32% to 9% among patients who underwent esophagectomy [41].

5.5. Incentive Spirometry

Incentive Spirometry was first introduced by Bartlett et al in the 1970s as a simple, method to encourage deep breathing exercises and sustained maximal inspirations in the postoperative patient [42]. At the time of its introduction, Bartlett and colleagues had found a significant reduction in the incidences of respiratory complications in the patient cohort that utilised incentive spirometry and concluded that voluntary maximal inspiration is highly effective in reversing altered pulmonary function after surgical and anaesthetic insult 42. Indeed, a recent randomised control trial by Zhao et al Has shown that volume incentive spirometry improves the haemodynamics and pulmonary function of patients following open abdominal surgery [43].

6. Chest Physiotherapy

Chest physiotherapy provides a means to postural drainage of pulmonary secretions and aims to prevent atelectasis by treating secretions obstructing small airways [39]. Targeted chest physiotherapy is not new in the rehabilitation realm, such that multiple studies in the last three decades have shown the use of chest physiotherapy is associated with significant reduction in the incidences of post- operative respiratory complications and chest infections [44- 47]. Besides the benefit of preventing post-operative respiratory complications, there is also an added benefit of cost-effectiveness for acute hospitals where the high costs associated with treatment of said complications can be avoided [48].

6.1. Use of Preventative Care Bundles

In the last two decades, there has been a considerable success in the change of intensive care unit practices globally since the introduction of ventilator-associated pneumonia care bundle by the Institute for Healthcare Improvement by Resar et al. [49]. Undoubtedly, combining a group of inter-related treatments strategies would make sense, especially with the common end-goal of reducing an important clinical hurdle such as post-operative pneumonia (POP). In more recent years, there have been various successful outcomes in the reduction of POP reported globally following the introduction of care bundles and post-operative pneumonia prevention programs. Of the reported studies, it appears to be universal that the collective use of incentive spirometry, head of bed elevation ≥ 30 degrees, perioperative oral care with chlorhexidine gargles, ambulation with adequate analgesia, regular coughing with deep breathing exercises and ongoing education of all surgical ward staff makes up the so-called bundle approach to preventing POP [50-54].

7. I Cough

In fact, Cassidy et al have coined a standardised and rather notable perioperative pulmonary care program known as I COUGH11 (short for ¬Incentive spirometry, Coughing and deep breathing,

Oral care, Understanding, Getting out of bed, and Head of bed elevation) in 2013, with a good outcome and reported reduction of incidence of postoperative pneumonia from 2.6% to 1.6% after its implementation. Associated risk-adjusted outcomes were also shown to decrease from an OR 2.13 to an OR of 1.5811. The I COUGH group have demonstrated that The I COUGH methodology is simple and achievable, which is crucial for successful implementation [39].However, it is worth noting that in a follow up study a decade down the line, Cassidy and colleagues have found that whilst there was initial improvement in outcomes, the loss of early program momentum and unfortunately local outcome have reverted to pre-program implementation rates of POP55. Whilst a less-than-ideal outcome, this demonstrates the importance of continued adherence to a newly implemented protocol so as to ensure sustainability and protracted success. This highlights the natural wax and wanes of initial momentum following introduction of a new protocol in an institution. There is a complex interaction of local population health concerns, dedication of stakeholders, financial supports, human resources and the organisational environment when it comes to the sustainability of a quality improvement project such as I COUGH55. This is an important message to be appreciated by anyone who intends to implement a new POP prevention program within their local hospital systems.

7.1. Summary and Conclusions

Emergency laparotomy is a costly and high stakes emergency general surgical procedure with associated high morbidity and mortality [1,9,56]. Post-operative respiratory complications such as POP represents a significant cause of morbidity and mortality [1,5,6]. following major abdominal surgery such as an emergency laparotomy. Yet, there is quite a sparse scientifically-based patient care pathways, especially in the peri- and post-operative period specific for emergency laparotomy [56,57]. Bundled standardised post-operative respiratory care pathways designed for major surgical procedures, such as I COUGH, coupled with a healthy culture of nursing education is essential for successful outcomes in preventing POP [5,11,55].In addition to targeted bundles to prevent post-operative pulmonary complications, more recent work have shown that it was possible to implement a more comprehensive and detailed perioperative protocol in emergency abdominal surgery with good compliance shown in a single centre in Denmark [58]. There remains considerable scope for future studies and further research into the implementation of simple and effective comprehensive recovery care bundles for patient who have had major emergency abdominal surgery.

References

1. NELA Project Team. Eighth patient report of the National Emergency Laparotomy Audit (NELA). London. 2024.
2. Peden CJ. Emergency surgery in the elderly patient: a quality improvement approach. Anaesthesia. 2011; 66: 440-5.
3. Saunders D, Murray D, Pichel AC. Variations in mortality after emergency laparotomy: the first report of the UK Emergency Laparotomy Network. British journal of anaesthesia. 2012;109(3):368-75.
4. Chughtai, Morad. “The Epidemiology and Risk Factors for Postoperative Pneumonia.” Journal of clinical medicine research.2017; 466-475.
5. Chughtai M, Gwam CU, Mohamed N. The epidemiology and risk factors for postoperative pneumonia. Journal of clinical medicine research. 2017;9(6):466.
6. Howes TE, Cook TM, Corrigan LJ, Dalton SJ. Postoperative morbidity survey, mortality and length of stay following emergency laparotomy. Anaesthesia. 2015;70(9):1020-7.
7. Xiang B, Jiao S, Si Y. Risk Factors for Postoperative Pneumonia: A Case-Control Study. Frontiers in Public Health. 2022;10:913897.
8. Guest JF, Keating T, Gould D, Wigglesworth N. Modelling the annual NHS costs and outcomes attributable to healthcare-associated infections in England. BMJ Open. 2020; 10(1): e033367-e033367.
9. Shapter SL, Paul MJ, White SM. Incidence and estimated annual cost of emergency laparotomy in England: is there a major funding shortfall?. Anaesthesia. 2012;67(5):474-8.
10. Li M, Pan P, Hu C.Pathogen distribution and antibiotic resistance for hospital aquired pneumonia in respiratory medicine intensive care unit].2013;38(3):251-257.
11. Cassidy MR, Rosenkranz P, McCabe K, Rosen JE. I COUGH: Reducing Postoperative Pulmonary Complications with a Multidisciplinary Patient Care Program. JAMA Surg. 2013;148(8):740-745.
12. Anthonisen NR, Wright EC, Hodgkin JE. Prognosis in chronic obstructive pulmonary disease. Am Rev Respir Dis. 1986;133(1):14-20.
13. Mannino DM, Doherty DE, Sonia Buist A. Global Initiative on Obstructive Lung Disease (GOLD) classification of lung disease and mortality: findings from the Atherosclerosis Risk in Communities (ARIC) study. Respir M. 2006;100(1):115-122.
14. Gupta H, Ramanan B, Gupta PK. Impact of COPD on postoperative outcomes: results from a national database. Chest. 2013;143(6):1599-1606.
15. Kroenke K, Lawrence VA, Theroux JF, Tuley MR. Operative risk in patients with severe obstructive pulmonary disease. Arch Intern Med. 1992;152(5):967-971.
16. Sakai RL, Abrao GM, Ayres JF. Prognostic factors for perioperative pulmonary events among patients undergoing upper abdominal surgery. Sao Paulo Med J. 2007;125(6): 315-321.
17. Corbin RP, Loveland M, Martin RR, Macklem PT. A four-year follow-up study of lung mechanics in smokers. American Review of Respiratory Disease. 1979;120(2):293-304.
18. Anthonisen NR, Connett JE, Murray RP. Smoking and lung function of Lung Health Study participants after 11 years. American journal of respiratory and critical care medicine. 2002;166(5):675-9.
19. Yang CK, Teng A, Lee DY, Rose K. Pulmonary complications after major abdominal surgery: National Surgical Quality Improvement Program analysis. Journal of Surgical Research. 2015;198(2):441-9.
20. Scholes RL, Browning L, Sztendur EM, Denehy L. Duration of anaesthesia, type of surgery, respiratory co-morbidity, predicted VO2max and smoking predict postoperative pulmonary complications after upper abdominal surgery: an observational study. Aust J Physiother. 2009;55(3): 191-198.
21. Christensen EF, Schultz P, Jensen OV. Postoperative pulmonary complications and lung function in high-risk patients: a com-parison of three physiotherapy regimens after upper abdominal surgery in general anesthesia. Acta Anaesthesiol. Scand. 1991; 35: 97-104.
22. Westbrook PR, Stubbs SE, Sessler AD, Rehler K, Hyatt RE. Effects of anesthesia and muscle paralysis on respiratory mechanics in normal man. J. Appl. Physiol. 1973; 34: 81-6.
23. Boyd-Carson H, Gana T, Lockwood S, Murray D, Tierney GM. A review of surgical and peri-operative factors to consider in emergency laparotomy care. Anaesthesia. 2020;75:e75-82.
24. Licker M, Schweizer A, Ellenberger C. Perioperative medical management of patients with COPD. Int J Chron Obstruct Pulmon Dis. 2007;2(4):493-515.
25. Canet J, Sabate S, Mazo V. Development and validation of a score to predict postoperative respiratory failure in a multicentre European cohort: a prospective, observational study. Eur J

Anaesthesiol. 2015; 32(7):458-470.

26. Visser A, Geboers B, Gouma DJ, Goslings JC, Ubbink DT. Predictors of surgical complications: a systematic review. Surgery. 2015;158(1): 58-65.
27. Kim TH, Lee JS, Lee SW, Oh YM. Pulmonary complications after abdominal surgery in patients with mild-to-moderate chronic obstructive pulmonary disease. International Journal of Chronic Obstructive Pulmonary Disease. 2016; 2785-96.
28. Marik PE. Aspiration pneumonitis and aspiration pneumonia. New England Journal of Medicine. 2001;344(9):665-71.
29. Drakulovic MB, Torres A, Bauer TT, Nicolas JM, Nogue S, Ferrer M. Supine body position as a risk factor for nosocomial pneumonia in mechanically ventilated patients: a randomised trial. Lancet. 1999;354:1851-8.
30. Kollef MH. Ventilator-associated pneumonia: a multivariate analysis. JAMA. 1993;270:1965-70.
31. de Larminat V, Montravers P, Dureuil B, Desmonts JM. Alteration in swallowing reflex after extubation in intensive care unit patients. Crit Care Med. 1995;23:486-90.
32. Tolep K, Getch CL, Criner GJ. Swallowing dysfunction in patients re- ceiving prolonged mechanical ventilation. Chest. 1996;109:167-72.
33. Venara A, Neunlist M, Slim K, Barbieux J, Colas PA, Hamy A, Meurette G. Postoperative ileus: pathophysiology, incidence, and prevention. Journal of visceral surgery. 2016;153(6):439-46.
34. Nagle RT, Leiby BE, Lavu H, Rosato EL, Yeo CJ, Winter JM. Pneumonia is associated with a high risk of mortality after pancreaticoduodenectomy. Surgery. 2017;161(4):959-967.
35. Smetana GW. Postoperative pulmonary complications: an update on risk assessment and reduction. Cleve Clin J Med 2009;76:S60-S65.
36. Dimick JB, Chen SL, Taheri PA, Henderson WG, Khuri SF, Campbell DA Jr. Hospital costs associated with surgical complications: a report from the private-sector National Surgical Quality Improvement Program. J Am Coll Surg. 2004;199(4):531-537.
37. Duggan M, McCaul CL, McNamara PJ, Engelberts D, Ackerley C, Kavanagh BP. Atelectasis causes vascular leak and lethal right ven- tricular failure in uninjured rat lungs. Am J Respir Crit Care Med. 2003;167(12):1633-1640.
38. vanKaam AH, Lachmann RA, Herting E. Reducing atelectasis attenuates bacterial growth and translocation in experimental pneumonia. Am J Respir Crit Care Med. 2004;169(30):1046-1053.
39. Branson RD. The scientific basis for postoperative respiratory care. Respiratory care. 2013;58(11):1974-84.
40. Soutome S, Hasegawa T, Yamguchi T, Aoki K, Kanamura N, Mukai T, Yamazoe J, Nishikawa M. Prevention of postoperative pneumonia by perioperative oral care in patients with esophageal cancer undergoing surgery: a multicenter retrospective study of 775 patients. Supportive Care in Cancer. 2020;28:4155-62.
41. Akutsu Y, Matsubara H, Shuto K. Pre-operative dental brushing can reduce the risk of postoperative pneumonia in esophageal cancer patients. Surgery. 2010; 147:497-502.
42. Bartlett RH, Brennan ML, Gazzaniga AB, Hanson EL. Studies on the pathogenesis and prevention of postoperative pulmonary complications. SurgGynecol Obstet. 1973;137(6):925-933.
43. Zhao CH, Sun YH, Mao XM. Volume Incentive Spirometry Reduces Pulmonary Complications in Patients After Open Abdominal Surgery: A Randomized Clinical Trial. International Journal of General Medicine. 2023; 793-801.
44. Morran CG, Finlay IG, Mathieson M. Randomized controlled trial of physiotherapy for postoperative pulmonary complications. Br J Anaesth. 1983;55(11):1113-1117.
45. Torrington KG, Sorenson DE, Sherwood LM. Postoperative chest percussion with postural drainage in obese patients following gastric stapling. Chest. 1984;86(7):891-895.
46. Christensen EF, Schultz P, Jensen OV, Egebo K, Engberg M, Grøn I, Juhl B. Postoperative pulmonary complications and lung function in high-risk patients: a comparison of three physiotherapy regimens after upper abdominal surgery in general anesthesia. Acta Anaesthe- siol Scand. 1991;35(2):97-104.
47. FagevikOlsén M, Hahn I, Nordgren S, Lönroth H, Lundholm K. Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. Journal of British Surgery. 1997;84(11):1535-8.
48. Boden I, Robertson IK, Neil A, Reeve J, Palmer AJ, Skinner EH, Browning L, Anderson L. Preoperative physiotherapy is cost-effective for preventing pulmonary complications after major abdominal surgery: a health economic analysis of a multicentre randomised trial. Journal of physiotherapy. 2020;66(3):180-7.
49. Resar R, Pronovost P, Haraden. Using a bundle approach to improve ventilator care processes and reduce ventilator-associated pneumonia. Joint Commission Journal on Quality and Patient Safety. 2005;31(5):243-248.
50. Kazaure HS, Martin M, Yoon JK, Wren SM. Long-term results of a postoperative pneumonia prevention program for the inpatient surgical ward. JAMA surgery. 2014;149(9):914-8.
51. Hiramatsu T, Sugiyama M, Kuwabara S, Tachimori Y, Nishioka M. Effectiveness of an outpatient preoperative care bundle in preventing postoperative pneumonia among esophageal cancer patients. Am J Infect Control. 2014; 42:385-388
52. Geerds MA, Folbert EC, Visschedijk SF, Klunder MB, Vollenbroek-Hutten MM, Hegeman JH. Implementation of a pneumonia prevention protocol to decrease the incidence of postoperative pneumonia in patients after hip fracture surgery. Injury. 2022;53(8):2818-22.
53. Lacerna CC, Patey D, Block L, Naik S, Kevorkova Y, Galin J, Parker M, Betts R. A successful program preventing nonventilator hospital-acquired pneumonia in a large hospital system. Infection Control & Hospital Epidemiology. 2020;41(5):547-52.
54. Wren SM, Martin M, Yoon JK, Bech F. Postoperative pneumonia-prevention program for the inpatient surgical ward. Journal of the American College of Surgeons. 2010;210(4):491-5.
55. Cassidy MR, Rosenkranz P, Macht RD, Talutis S, McAneny D. The I COUGH multidisciplinary perioperative pulmonary care program: one decade of experience. The Joint Commission Journal on Quality and Patient Safety. 2020;46(5):241-9.
56. Foss NB, Kehlet H. Challenges in optimising recovery after emergency laparotomy. Anaesthesia. 2020;75:e83-9.
57. Odor PM, Bampoe S, Gilhooly D, Creagh-Brown B, Moonesinghe SR. Perioperative interventions for prevention of postoperative pulmonary complications: systematic review and meta-analysis. Bmj. 2020;368.
58. Burcharth J, Abdulhady L, Danker J, Ekeloef S, Jørgensen T, Lauridsen H, Lunen TB. Implementation of a multidisciplinary perioperative protocol in major emergency abdominal surgery. European Journal of Trauma and Emergency Surgery. 2021;47:467-77.