

Appendix Table 1. Study Characteristics of Univariate Studies of Clinical Risk Factors*

Author, Year (Reference)	Study Type†	Timeline	Type of Surgery	Specific PPCs Studied	Inclusion Criteria
Fasth et al., 1980 (19)	Cohort	Prospective	Bowel resection for Crohn disease	Pneumonia	
Warren and Grimwood, 1980 (20)	Cohort	Retrospective	Open cholecystectomy	Atelectasis, pneumonia	
Wirén and Janzon, 1983 (21)	Cohort	Retrospective	Gall bladder or peptic ulcer surgery	Pneumonia or atelectasis	Elective
Seymour and Pringle, 1983 (22)	Cohort	Prospective	General surgery	Pneumonia	Age > 65 y
Diehl et al., 1983 (23)	Cohort	Retrospective	AAA repair	Pneumonia, respiratory failure	
Buckwalter and Herbst, 1983 (24)	Cohort	Prospective	Gastric bypass	All that prolonged hospitalization or required treatment	
Galicier and Richet, 1985 (25)	Cohort	Prospective	All	Pneumonia	
Beard et al., 1986 (26)	Cohort	Prospective	All	Respiratory depression, bronchospasm, cyanosis, respiratory congestion, dyspnea, pneumothorax, atelectasis, laryngospasm	
Matsumata et al., 1987 (27)	Case series 25–99	Retrospective	Hepatic resection	Pleural effusion	
Fogh et al., 1987 (28)	Cohort	Prospective	Major abdominal	Pneumonia, atelectasis, respiratory failure	
Zelcher and Wells, 1987 (29)	Cohort	Prospective	All	Cyanosis, bronchospasm, laryngospasm, aspiration, reintubation, hypoventilation	
Fasth et al., 1987 (30)	RCT	Prospective	Colorectal surgery	Pneumonia	
Hollier et al., 1988 (31)	Cohort	Retrospective	Thoracoabdominal aortic aneurysm repair	Respiratory failure	
Poe et al., 1988 (32)	Cohort	Prospective	Elective cholecystectomy	Atelectasis, pneumonia, purulent bronchitis	
Jørgensen et al., 1988 (33)	Cohort	Retrospective	Abdominal	Pneumonia	All patients had fever
Roberts et al., 1988 (34)	Cohort	Prospective	Elective abdominal	Atelectasis	
Tartter, 1988 (35)	Cohort	Retrospective	Colorectal cancer	Pneumonia	
Mellors et al., 1988 (36)	Cohort	Prospective	Abdominal	Pneumonia	
Pien et al., 1988 (37)	Cohort with comparison	Retrospective	All	Asthma exacerbation, pneumonia	Asthma prompting preoperative medical consultation, use of inhaled steroids or alternate-day prednisone
Nielsen et al., 1989 (38)	Cohort	Prospective	Upper abdominal	Pleural effusion, atelectasis	Elective upper abdominal surgery
Ejlertsen et al., 1989 (39)	Cohort	Retrospective	Elective upper abdominal	Pneumonia	
Vodinh et al., 1989 (40)	Cohort	Prospective	Vascular	Pneumonia, atelectasis, pleural effusion, respiratory failure	
Seymour and Vaz, 1989 (41)	Cohort	Prospective	Noncardiac	Pneumonia, atelectasis	Age > 65 y

Appendix Table 1—Continued

Exclusion Criteria	Other Footnotes	Hierarchy of Research Design‡	Study Quality	Considered All Key Confounders: Type of Surgery, Age, COPD	Patients, n	PPCs, n	Mean Age, y	Men, %
None		II-3	Fair	No	153	2		
None		II-3	Poor	No	194	42	52	70
None		II-3	Poor	No	52	28	53	100
None		II-3	Poor	No	258	102	NA	57
None		II-3	Poor	No	557	33	63	81
None		II-3	Poor	No	565	3	40	36
ACS class IV (dirty) procedures		II-3	Poor	No	693	23	NA	NA
None	Studied only immediate postoperative complications in PACU	II-2	Poor	No	2293	44	NA	NA
Postoperative subphrenic abscess, thoracoabdominal incision		II-3	Poor	No	80	40	56	74
None		II-3	Poor	No	125	23	NA	NA
None	Studied only immediate postoperative complications in PACU	II-2	Poor	No	443	10	NA	NA
None		II-3	Poor	No	92	5	NA	NA
None		II-3	Poor	No	101	33	69	60
None		II-2	Fair	No	209	31		26
Surgery < 1 h duration		II-3	Fair	No	259	47	NA	NA
None		II-3	Good	No	270	154		
Liver or other metastatic lesions		II-2	Fair	No	343	6	69	50
Gynecologic surgery, age < 16 y		II-2	Fair	No	434	4		
None		II-2	Poor	No	4121	36	51	32
Medical treatment for heart or lung disease, elevated serum creatinine level, CHF on preoperative chest radiograph		II-2	Poor	No	128	89	59	37
Preoperative pulmonary, cardiovascular, renal, or hepatic disease		II-2	Poor	No	130	11	53.1	NA
Life-threatening emergency surgery, carotid surgery, varicose vein surgery		II-2	Poor	No	151	56	61	85
None		II-3	Poor	No	288	40	NA	NA

Appendix Table 1—Continued

Author, Year (Reference)	Study Type†	Timeline	Type of Surgery	Specific PPCs Studied	Inclusion Criteria
Koness et al., 1990 (42)	Cohort	Retrospective	Perforated peptic ulcer	Respiratory failure	
Patrick et al., 1990 (43)	Cohort	Retrospective	All	Pneumonia, respiratory failure	Neuromuscular restrictive pulmonary physiology requiring continuous or intermittent mechanical ventilation at baseline
Verdeil et al., 1990 (44)	Cohort	Prospective	Vascular	Pneumonia	
Arriaga et al., 1990 (45)	Cohort	Retrospective	Laryngectomy	Respiratory failure	
Pinto et al., 1991 (46)	Cohort	Retrospective	Gastric cancer	Pneumonia	
Hall et al., 1991 (47)	Cohort	Prospective	Abdominal	Atelectasis, pneumonia	Manipulation of abdominal viscera
Greco et al., 1991 (48)	Cohort	Prospective	All	Pneumonia	Any surgery
Katz et al., 1992 (49)	Case series 25–99	Prospective	Aortic	Pneumonia, respiratory failure	Elective aortic reconstruction
Kroenke et al., 1992 (50)	Cohort	Retrospective	All	All	Severe COPD with FEV ₁ < 50%, predicted and FEV ₁ :FVC < 70%
Dilworth et al., 1991 (51)	Cohort	Prospective	Upper abdominal	Pneumonia	
Kispert et al., 1992 (52)	Cohort	Retrospective	Major vascular	Pneumonia, respiratory failure, ARDS	Elective
Brooks-Brunn, 1992 (53)	Cohort	Retrospective	Open cholecystectomy	Pneumonia, atelectasis	
Braga et al., 1992 (54)	Cohort	Retrospective	Gastric, colorectal, or pancreatic cancer	Pneumonia	
Evaldson et al., 1992 (55)	Cohort	Prospective	Obstetric and gynecologic	Pneumonia	Obstetric and gynecologic
Iwamoto et al., 1993 (56)	Case series	Retrospective	Thoracic, abdominal, or neurosurgery	Pneumonia	
Jayr et al., 1993 (57)	Cohort	Prospective	Intraabdominal vascular	Respiratory failure	Midline incision
Kroenke et al., 1993 (58)	Cohort	Retrospective	Major abdominal and nonresective thoracic	Atelectasis, bronchospasm, pneumonia, respiratory failure	Severe COPD with FEV ₁ < 50%, predicted and FEV ₁ :FVC, < 70%

Appendix Table 1—Continued

Exclusion Criteria	Other Footnotes	Hierarchy of Research Design‡	Study Quality	Considered All Key Confounders: Type of Surgery, Age, COPD	Patients, n	PPCs, n	Mean Age, y	Men, %
None	Can't assess effect of risk factors because analysis only evaluated effect of risk factors on mortality	II-3	Poor	No	109	16	67	55
None		II-3	Poor	No	142	17	NA	NA
None		II-3	Poor	No	329	5	NA	NA
None		II-3	Poor	No	414	74	62	NA
Hospital stay < 7 d	Can't assess effect of risk factors because all infectious complications were combined	II-3	Fair	No	196	18	67	60
Hernia repair, declined consent, ICU care immediately after surgery		II-2	Fair	No	1000	232	54	53
Inadequate data collection	Included only preintervention patients	II-3	Poor	No	4096	119	47	
None		II-3	Poor	No	64	24	67	44
None		II-2	Fair	Yes	107	34	66	72
None		II-2	Poor	No	127	26	56	39
None		II-2	Poor	No	147	19	65	77
Age < 12 y, surgeries other than cholecystectomy at same time, preoperative pneumonia or atelectasis	Did not abstract risk factor data because author chose to include only a sampling (54 of 209) of patients with no PPC for risk factor analysis	II-2	Poor	No	263	54	NA	NA
Age > 80 y, antibiotic use in previous 2 d, emergency surgery, palliative surgery		II-2	Fair	No	285	8	59	46
Dilation and curettage, abortion, noncesarean obstetric procedures	Can't assess effect of risk factors because all infectious complications were combined	II-3	Poor	No	2361	8	NA	0
Age < 20 y	PPC was postoperative pneumonia identified by discharge diagnoses only	II-3	Poor	No	4380	30		
None		II-2	Poor	No	51	12		65
None	Excluded risk factor analysis that looked at risk for severe PPC or death; subcategorized COPD into severe (PPC rate: 17/26) and mild or moderate (PPC rate: 27/52)	II-2	Good	Yes	130	64	63	68

Appendix Table 1—Continued

Author, Year (Reference)	Study Type†	Timeline	Type of Surgery	Specific PPCs Studied	Inclusion Criteria
Ephgrave et al., 1993 (59)	Cohort	Prospective	Any requiring postoperative nasogastric tube	Pneumonia	Postoperative nasogastric tube, male veterans
Calligaro et al., 1993 (60)	Cohort	Retrospective	AAA repair	Pneumonia, respiratory failure	AAA repair
Heiss et al., 1993 (61)	RCT	Prospective	Colorectal cancer	Pneumonia	Hemoglobin level > 125 g/L
Weber et al., 1993 (62)	RCT	Prospective	Head and neck oncologic surgery	Pneumonia, bronchitis	
Money et al., 1994 (63)	Cohort	Retrospective	Thoracoabdominal aortic aneurysm repair	Respiratory failure	
Charash et al., 1994 (64)	Cohort	Retrospective	Femur fracture repair	Pulmonary contusion, pneumonia, fat embolism, pulmonary embolism	Blunt midshaft femur fracture stabilized with intramedullary nail, injury severity score > 17
Gefke et al., 1994 (65)	Cohort	Retrospective	Abdominal aortic	Respiratory failure	
Arvidsson et al., 1994 (66)	Cohort	Prospective	Elective	Respiratory arrest, aspiration, respiratory distress, pneumonia, pleuritis, hydrothorax, pneumothorax, atelectasis, asthmatic obstruction	Adults, surgery requiring incision, anticipated hospital stay at least 24 h
Lawrence et al., 1995 (67)	Case-control	Retrospective	Abdominal	Pneumonia, respiratory failure, bronchospasm, bronchitis, pleural effusion	
Kabalin et al., 1995 (68)	Case series 25–99	Retrospective	All	Asthma exacerbation	Asthma prompting preoperative medical consultation
Gilling-Smith et al., 1995 (69)	Cohort	Retrospective	Thoracoabdominal aortic aneurysm repair	Pneumonia, respiratory failure	
Liedman et al., 1995 (70)	Cohort	Retrospective	Esophageal or gastric cancer	Pneumonia, respiratory failure	
Choban et al., 1995 (71)	Cohort with comparison	Retrospective	General, urologic, gynecologic, or thoracic	Pneumonia	
Hall et al., 1996 (72)	Case-control	Retrospective	Open cholecystectomy	Lung collapse or consolidation	ASA class I–II, general anesthesia
Kocabas et al., 1996 (73)	Cohort	Prospective	Elective upper abdominal	Pneumonia, bronchitis, atelectasis, pulmonary embolism	
Warner et al., 1996 (74)	Cohort	Retrospective	All	Bronchospasm, laryngospasm	General anesthesia or neuraxial blockade
Wolters et al., 1996 (75)	Cohort	Prospective	General or vascular	Pneumonia, atelectasis, pleural effusion	
Rose et al., 1996 (76)	Cohort	Prospective	Inpatient	Unplanned mechanical ventilation	
Ferguson et al., 1997 (77)	Cohort	Retrospective	Esophagectomy	Pneumonia, respiratory failure, atelectasis	
Delgado-Rodríguez et al., 1997 (78)	Cohort	Prospective	General surgery	Pneumonia	
Thomas et al., 1997 (3)	Cohort with comparison	Prospective	Elective noncardiac	Respiratory failure, pneumonia	Age > 50 y, expected length of stay at least 2 d

Appendix Table 1—Continued

Exclusion Criteria	Other Footnotes	Hierarchy of Research Design‡	Study Quality	Considered All Key Confounders: Type of Surgery, Age, COPD	Patients, n	PPCs, n	Mean Age, y	Men, %
None		II-2	Poor	No	140	26	63	100
Emergency surgery, concomitant nonvascular surgery, retroperitoneal incision		II-3	Poor	No	181	97		
Acute infection, age > 75 y, history of seizures, unstable CAD, ASA class > III, unresectable tumor	Can't assess effect of risk factors because all infectious complications were combined	I	Fair	No	120	3	60	51
None		II-2	Fair	No	225	22	59	79
Death within 12 h of surgery, incomplete database	No quantifiable risk factor data	II-3	Fair	Yes	90	19	66.8	
Death due to head trauma or hemorrhagic shock		II-3	Poor	No	138	33	30	71
None		II-3	Poor	No	553	77	NA	NA
None	Can't assess effect of risk factors because all complications were combined	II-2	Poor	No	1361	39	57	55
Atelectasis		II-2	Good	No	2291	82	65	NA
None		II-2	Poor	No	89	3	46	24
None		II-3	Poor	No	130	49	67	73
None		II-2	Fair	No	213	62	66	69
Pregnant, postpartum, incomplete database		II-3	Poor	No	849	1	50	NA
No consent, age < 14 y, preexisting pulmonary complication, known chronic airway disease		II-2	Poor	No	95	12	48	24
None		II-3	Poor	No	60	21	48.3	60
None		II-2	Poor	No	706	12	18	52
None		II-2	Good	Yes	6301	399	52	59
Cardiac surgery, neurosurgery, preoperative ICU stay		II-2	Poor	No	15 059	41	NA	50
None		II-2	Fair	No	269	125	57.5	70
Hospital stay < 1 d		II-2	Fair	Yes	1483	19	53	47
None		II-2	Fair	No	2964	53	67	0.48

Appendix Table 1—Continued

Author, Year (Reference)	Study Type†	Timeline	Type of Surgery	Specific PPCs Studied	Inclusion Criteria
Schwilk et al., 1997 (79)	Cohort with comparison	Prospective	All	Reintubation, laryngospasm, bronchospasm, aspiration, hypoventilation	
Gillinov and Heitmiller, 1998 (80)	Cohort	Retrospective	Transhiatal esophagectomy	Pneumonia, pleural effusion requiring drainage, COPD exacerbation	
Kuwano et al., 1998 (81)	Cohort	Retrospective	Esophagectomy	Pneumonia, respiratory failure, hypoxemia	Right thoracoabdominal approach to esophagectomy
Midorikawa et al., 1999 (82)	Cohort	Retrospective	Hepatic resection	Pneumonia, atelectasis, pleural effusion	Hepatic tumor
Manninen et al., 1999 (83)	Cohort	Prospective	Neurosurgery	Respiratory rate < 8 breaths/min, oxygen saturation < 90%, dyspnea, bronchospasm, reintubation, pulmonary edema	
Reilly et al., 1999 (84)	Cohort	Prospective	Noncardiac	Pneumonia, respiratory failure, ARDS, hypoxia, bronchospasm	
Ziser et al., 1999 (85)	Cohort	Retrospective	All	Respiratory failure, pneumonia, ARDS	Cirrhosis by liver biopsy or impaired liver function tests plus abnormal imaging results
Haga et al., 1999 (86)	Cohort	Retrospective	All	Pneumonia	
Carson et al., 1999 (87)	Cohort	Retrospective	Hip fracture repair	Pneumonia	
Gibbs et al., 1999 (88)	Cohort	Prospective	Noncardiac	Pneumonia, respiratory failure	
Brooks-Brunn, 2000 (89)	Cohort	Retrospective	Total abdominal hysterectomy	Pneumonia, atelectasis, lasting at least 48 h	Elective surgery, anticipated stay > 48 h
Oñate-Ocaña et al., 2000 (90)	Cohort	Retrospective	Gastric cancer	Pneumonia, respiratory distress	
Yamashita et al., 2000 (91)	Cohort	Retrospective	Gastric cancer	Pneumonia	Elective gastrectomy
Gupta et al., 2001 (92)	Case-control	Retrospective	Hip or knee replacement	Reintubation, hypercapnia, hypoxemia	Symptoms and signs of OSA, abnormal sleep study or suggestive overnight oximetry
Girish et al., 2001 (93)	Case series 25-99	Prospective	Thoracotomy, sternotomy, or upper abdominal surgery	Pneumonia, respiratory failure, atelectasis	
Hajzman et al., 2001 (94)	Cohort	Retrospective	Gastric banding for obesity surgery	Respiratory failure, chronic bronchitis exacerbation	Morbid obesity
Kinugasa et al., 2001 (95)	Cohort	Retrospective	Esophagectomy	Pneumonia, pulmonary edema, atelectasis, hypoxia requiring reintubation	Squamous-cell cancer of thoracic esophagus
Polanczyk et al., 2001 (96)	Cohort	Prospective	Major elective noncardiac	Pneumonia, respiratory failure	Age > 50 y; major nonemergent, noncardiac surgery
Polanczyk et al., 2001 (97)	Cohort	Prospective	Nonemergent major noncardiac	Pneumonia, respiratory failure	Age > 50 y; major nonemergent, noncardiac surgery
Griffin et al., 2002 (98)	Cohort	Prospective	Ivor Lewis subtotal esophagectomy	Pneumonia, respiratory failure	

Appendix Table 1—Continued

Exclusion Criteria	Other Footnotes	Hierarchy of Research Design‡	Study Quality	Considered All Key Confounders: Type of Surgery, Age, COPD	Patients, n	PPCs, n	Mean Age, y	Men, %
Age < 16 y, emergency surgery		II-2	Poor	No	26 961	1114	NA	NA
None	Major pulmonary complications only	II-2	Poor	No	101	11	60	89
		II-3	Poor	No	178	23	63	88
Bile duct carcinoma, gall bladder carcinoma		II-3	Poor	No	277	82	61	75
Surgery for chronic pain or movement disorder, postoperative ventilation > 4 h		II-2	Poor	No	486	31	52	53
Minor procedures	Poor functional status was inability to walk 4 blocks or climb 2 flights by self-report	II-1	Good	Yes	600	48	63	41
Liver transplantation		II-2	Good	Yes	733	91	59.4	54
None		II-2	Good	Yes	1281	27	60	48
Declined blood transfusion, metastatic cancer, several traumatic injuries		II-2	Good	Yes	9598	337	80.3	21
Minor procedures, organ transplantation	Estimated number of PPCs	II-2	Fair	Yes	54 215	6470	61	97
Age < 18 y		II-2	Poor	No	120	13	47	0
Age < 18 y		II-3	Fair	No	208	8	58	49
Preoperative infection, immunocompromised, pancreatic resection, colon resection, postoperative deaths unrelated to infection	Can't assess effect of risk factors because all infectious complications were combined	II-3	Poor	No	367	7		
None		II-2	Poor	No	202	40	68	70
No lung resection if predicted FEV ₁ < 800 mL or 40%		II-2	Fair	Yes	83	25	67	63
None		II-3	Poor	No	114	4	40	14
None		II-2	Poor	No	246	54	NA	77
AAA repair		II-2	Good	Yes	4059	91	66	53
Non-English-speaking, unable to give consent		II-2	Good	Yes	4315	122	67	48
None		II-3	Poor	No	228	39	64	70

Appendix Table 1—Continued

Author, Year (Reference)	Study Type†	Timeline	Type of Surgery	Specific PPCs Studied	Inclusion Criteria
Lawrence et al., 2002 (2)	Cohort	Retrospective	Hip fracture repair	Pneumonia, respiratory failure	Age ≥ 60 y
Blouw et al., 2003 (99)	Cohort	Retrospective	Gastric bypass	Atelectasis, respiratory failure, aspiration	

* AAA = abdominal aortic aneurysm; ACS = American College of Surgeons; ARDS = acute respiratory distress syndrome; ASA = American Society of Anesthesiologists; CAD = coronary artery disease; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; ICU = intensive care unit; NA = not available; OSA = obstructive sleep apnea; PACU = post-anesthesia care unit; PPC = postoperative pulmonary complication; RCT = randomized, controlled trial.

† Numbers are numbers of participants.

‡ Based on criteria from the U.S. Preventive Services Task Force (12).

Appendix Table 1—Continued

Exclusion Criteria	Other Footnotes	Hierarchy of Research Design‡	Study Quality	Considered All Key Confounders: Type of Surgery, Age, COPD	Patients, n	PPCs, n	Mean Age, y	Men, %
Declined blood transfusion, metastatic cancer, multiple myeloma, several traumatic injuries, additional operation besides hip fracture repair, leg amputation above the knee, paraplegia or quadriplegia		II-2	Poor	No	8930	344	80.2	79
No patient consent for chart review, reoperation		II-2	Poor	No	197	23	47	31