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CHEST
Special Feature

Respiratory Physiotherapy To Prevent Pulmonary Complications After Abdominal Surgery*

A Systematic Review

Patrick Pasquina; Martin R. Tramèr, MD, DPhil; Jean-Max Granier; and Bernhard Walder, MD

Objectives: **To examine the efficacy of respiratory physiotherapy for prevention of pulmonary complications after abdominal surgery.**

Methods: **We searched in databases and bibliographies for articles in all languages through November 2005. Randomized trials were included if they investigated prophylactic respiratory physiotherapy and pulmonary outcomes, and if the follow-up was at least 2 days. Efficacy data were expressed as risk differences (RDs) and number needed to treat (NNT), with 95% confidence intervals (CIs).**

Results: **Thirty-five trials tested respiratory physiotherapy treatments. Of 13 trials with a "no intervention" control group, 9 studies (n = 883) did not report on significant differences, and 4 studies (n = 528) did: in 1 study, the incidence of pneumonia was decreased from 37.3 to 13.7% with deep breathing, directed cough, and postural drainage (RD, 23.6%; 95% CI, 7 to 40%; NNT, 4.3; 95% CI, 2.5 to 14); in 1 study, the incidence of atelectasis was decreased from 39 to 15% with deep breathing and directed cough (RD, 24%; 95% CI, 5 to 43%; NNT, 4.2; 95% CI, 2.4 to 18); in 1 study, the incidence of atelectasis was decreased from 77 to 59% with deep breathing, directed cough, and postural drainage (RD, 18%; 95% CI, 5 to 31%; NNT, 5.6; 95% CI, 3.3 to 19); in 1 study, the incidence of unspecified pulmonary complications was decreased from 47.7% to 21.4 to 22.2% with intermittent positive pressure breathing, or incentive spirometry, or deep breathing with directed cough (RD, 25.5 to 26.3%; NNT, 3.8 to 3.9). Twenty-two trials (n = 2,734) compared physiotherapy treatments without no intervention control subjects; no conclusions could be drawn.**

Conclusions: **There are only a few trials that support the usefulness of prophylactic respiratory physiotherapy. The routine use of respiratory physiotherapy after abdominal surgery does not seem to be justified.**
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Key words: abdominal surgery; atelectasis; continuous positive airway pressure; incentive spirometry; intermittent positive pressure breathing; metaanalysis; physical therapy; pneumonia; respiratory physiotherapy

Abbreviations: CI = confidence interval; CPAP = continuous positive airway pressure; FIO_2 = fraction of inspired oxygen; IPPB = intermittent positive pressure breathing; IS = incentive spirometry; NNT = number needed to treat; RD = risk difference

More than 4 million abdominal surgeries are performed in the United States every year.[1] Patients undergoing abdominal surgery are at increased risk for pulmonary complications postoperatively.[2] Postoperative pulmonary complications increase hospital morbidity, prolong hospital stay, and contribute to additional health-care costs.[3]

Postoperative pulmonary complications seem to be related to the disruption of the normal activity of respiratory muscles, a phenomenon that starts at induction of anesthesia and continues into the postoperative period.[4] Anesthetics, phrenic nerve dysfunction, and surgical trauma all impair the function of respiratory muscles after surgery. These mechanisms lead to a decrease in functional residual and vital capacity for many days, and subsequently to atelectasis. In an animal study,[5] atelectasis was shown to promote bacterial growth due to reduced function of alveolar macrophage and reduced functional surfactant, explaining the risk of pneumonia.

Postoperative chest physiotherapy was implemented in the beginning of the 20th century; deep breathing exercise was one of the first methods.[6] Subsequently, a variety of manual treatments including percussion, clapping, vibration, or shaking were developed to improve bronchial drainage. More recently, mechanical breathing devices such as incentive spirometry (IS), blow bottles, intermittent positive pressure breathing (IPPB), and continuous positive airway pressure (CPAP) were introduced into clinical practice. In 1994, a metaanalysis[7] concluded that prophylactic incentive spirometry and deep-breathing exercises were beneficial after abdominal surgery; however, an amalgamation of a variety of different pulmonary end points (for instance, atelectasis, pneumonia, or bronchitis) was analyzed. Thus, the clinical relevance of this positive finding remained unclear. Subsequently, two further metaanalyses[8,9] studied the impact of prophylactic respiratory physiotherapy on more specific postoperative pulmonary complications, *ie*, atelectasis or pneumonia. Overend et al[8] concluded that incentive spirometry was of no use after cardiac or abdominal surgery, and we were unable to find any evidence that a variety of physiotherapy treatments were beneficial after cardiac surgery.[9]

Some methods of respiratory physiotherapy are labor intensive and costly, and some may even induce specific adverse effects.[9] To justify the routine use of prophylactic respiratory physiotherapy after major surgery, we need to be confident that the efficacy is worthwhile and that there is a minimal likelihood of harm. Discrepancies in the conclusions of previous metaanalyses may be explained by differences in the selection of analyzed trials and by variations in the choice of analyzed end points. We set out to review the evidence that prophylactic respiratory physiotherapy prevented pulmonary complications after abdominal surgery.

Materials and Methods

As in a previous, similar analysis,[9] we took two *pre hoc* decisions to ensure that our conclusions were based on both clinically relevant and methodologically valid data. First, in the context of postoperative pulmonary complications, a reduction of pneumonia was of primary interest. Second, in the absence of a "gold standard" intervention, a randomized comparison between a physiotherapy method and a "no intervention" control was the most valid study design to establish the relative efficacy of physiotherapy.[9]

Studies were identified using MEDLINE, EMBASE, CINAHL, and the Cochrane Controlled Trials Register. The search strategy included the free-text terms *physical therapy, respiratory therapy, breathing exercise, chest physiotherapy, continuous positive airway pressure, incentive spirometry, intermittent positive pressure breathing, noninvasive positive pressure ventilation, bilevel positive airway pressure ventilation, blow bottles, positive expiratory pressure, postural drainage, abdominal surgery, cholecystectomy, gastrectomy, pancreas, colectomy, laparotomy, biliary tract, gastric,* and *random.* The last electronic search was in November 2005. Reference lists from retrieved reports and from review articles[7,8,10,11] were reviewed to identify additional studies. Articles in all languages were considered. We contacted the original investigators by letter and asked for supplementary data related to their study, and for unpublished data.

Criteria for Inclusion

We included full reports of randomized trials of patients undergoing open abdominal surgery. As in a previous similar analysis,[9] we did not consider trials with inadequate randomization methods (for instance, group assignment according to patients' date of birth, or alternate). Relevant trials had to compare any technique of prophylactic respiratory physiotherapy (active intervention) with no intervention (inactive control) or with another method of respiratory physiotherapy (active control). Studies that tested therapeutic physiotherapy to treat pulmonary complications were not considered. Trials had to report on one of five end points: atelectasis, pneumonia, postoperative pulmonary complications, oxygenation (PaO_2/fraction of inspired oxygen [FIO_2] ratio), and vital capacity. Trials were included if they reported on an observation period of at least 2 days. If end points were reported at different time points, we considered the longest observation period. Information on adverse effects that could be attributed to physiotherapy was also extracted.

Assessment of Quality of Data Reporting

Data abstraction was carried out by one investigator and independently reviewed by two others. We assessed for each included study the method of randomization and of concealment of treatment allocation, the degree of blinding, and completeness of follow-up.[12] We assumed that in this specific clinical setting, patient and care givers could not be blinded. Extracted data and quality scores were compared; in case of disagreement, consensus was reached by discussion.

Data Analysis

We recalculated dichotomous data on absence or presence of pulmonary complications as risk differences (RDs) with 95%

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Mr. Pasquina initiated, designed, and organized the study, searched trials, and extracted data. Dr. Tramèr designed the study and cross-checked extracted data. Mr. Granier cross-checked extracted data. Dr. Walder initiated and designed the study and cross-checked extracted data. All authors participated in interpreting the results of the trials and in writing the article.

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confidence intervals (CIs).[13] When the 95% CI around the RD excluded zero, we assumed that the difference between groups was statistically significant. For statistically significant results, the number needed to treat (NNT), the reciprocal of the RD, was computed as an estimate of the clinical relevance of a treatment effect.[14] Event rate scatters were used to explore the variability in the incidence of outcomes.

Results

Trial Characteristics

We screened 437 reports; 62 were considered for inclusion, but 27 were subsequently excluded (Fig 1). There was one redundancy unit[15]; we regarded the more detailed article as the original report[16] and excluded the duplicate.[17] We eventually analyzed data from 35 randomized trials with data on 4,145 adult patients (Table 1).[16,18–51] Trials came from 12 countries and were published between 1952 and 2005. Six authors[23,24,32,33,35,42,46] responded to our inquiry; all provided supplementary information that could be used for analysis. Of the 14 trials that were included in the systematic review by Thomas and McIntosh,[7] we included 11 trials[16,19,22,26,27,36,41,43,47,48] but rejected 3 trials (2 used a pseudorandomization,[52,53] and 1 was published as an abstract only[54]). Average group size was 51 patients (range, 8 to 445). Eleven trials (31%) described an adequate method of randomization; in 5 trials (14%), treatment allocation was concealed; in 16 trials (46%), observers were blinded; and in 13 trials (37%), follow-up of patients was complete. A large variety of physiotherapy treatments and combinations thereof were tested; they were administered for a period of 1 to 9 days (average, 4 days). Observation periods were 2 to 15 days (average, 5 days).

Active Intervention vs No Intervention Control

Thirteen trials[16,19,20,22,24,31,37,40,42,43,45,48,51] (n = 1,411) had a no intervention control group (Table 1). Six trials[16,20,24,42,43,48] (n = 614) with no intervention control subjects reported on pneumonia (Fig 2). In one trial,[43] the incidence of pneumonia without physiotherapy was 37.3% and was significantly decreased to 13.7% with deep breathing and directed cough and postural drainage (RD, 23.6%; 95% CI, 7 to 40%; NNT, 4.3; 95% CI, 2.5 to 14). This trial[43] reported on the highest incidence of pneumonia in control subjects of all trials; in the other studies,[16,20,24,42,48] the incidence of pneumonia in control subjects was much lower and very similar, between 2% and 5%. In two studies,[16,42] deep breathing with directed cough with or without postural drainage increased the incidence of pneumonia; differences, however, were not statistically significant.

Nine trials[16,22,24,31,37,42,43,48,51] (n = 861) with no

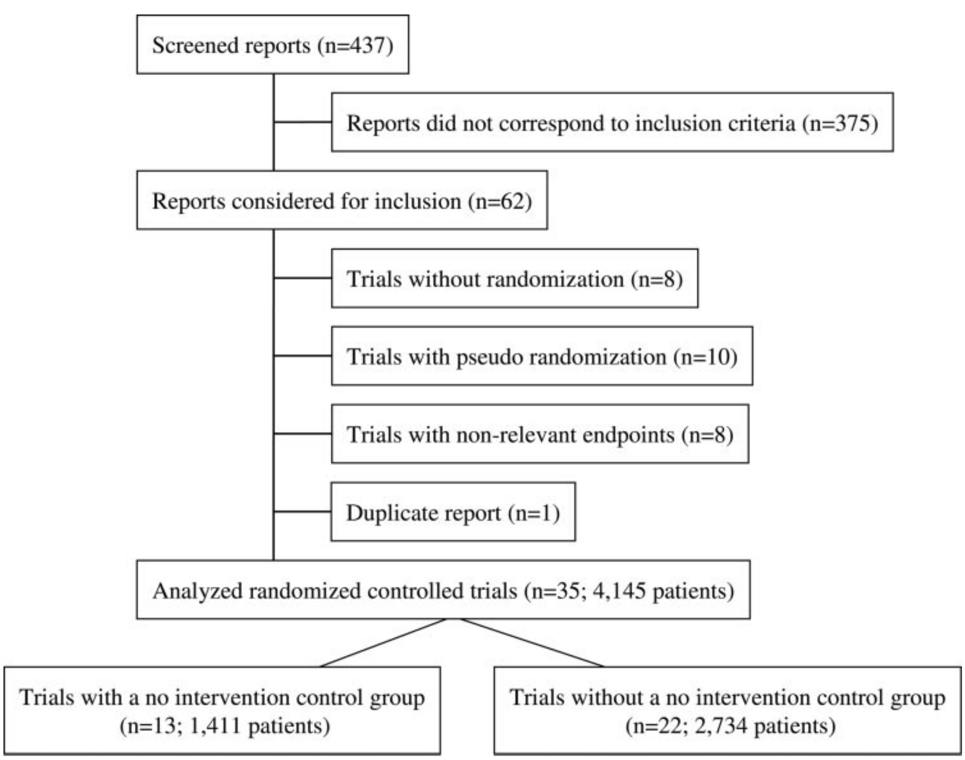

Figure 1. Flow chart of screened, excluded, and eventually analyzed reports.

Table 1—*Analyzed Randomized Trials**

Study	Surgery	Physiotherapy, No. of Patients: IS	CPAP	PT	IPPB	Other	No Intervention Control	Length of Therapy, d
Active intervention vs no intervention control								
Baxter and Levine,[19] 1969	Upper abdominal				50/50†		100	3
Böhner et al,[20] 2002	Abdominal vascular		99				105	1
Celli et al,[22] 1984	Upper and lower	42		41‡	45		44	4
Chumillas et al,[24] 1998	Upper abdominal			40‡			41	7
Giroux et al,[31] 1987	Hysterectomy			27‡			27	3
Hallbook et al,[16]1984	Cholecystectomy			45§/47‖			45	3
Laszlo et al,[37] 1973	Upper and lower			12§			13	5
Lotz et al,[40] 1984	Upper and lower		32				32	1
Mackay et al,[42] 2005	Upper and lower			29‡			21	4
Morran et al,[43] 1983	Cholecystectomy			51§			51	2
Palmer and Sellick,[45] 1952	Inguinal hernia			40¶			42	5
Schwieger et al,.[48] 1986	Cholecystectomy	20					20	3
Wiklander and Norlin,[51] 1957	Gastric or biliary			100§			100	3
Active intervention vs active intervention								
Ali et al,[18]1984	Cholecystectomy			15§	15			4
Campbell et al,[21] 1986	Upper and lower			35‡		36††		4
Christensen et al,[23] 1991	Gastric or biliary			17§		17††/17‡‡		3
Condie et al,[25] 1993	Upper and lower			152/158†‡				3
Craven et al,[26] 1974	Upper abdominal	35		35#				5
Crawford et al,[27] 1990	Cholecystectomy			30#		30§§		5
Denehy et al,[28] 2001	Upper and lower		17/15†	18				3
Dohi and Gold,[29] 1978	Upper and lower	34			30			5
Ebeo et al,[30] 2002	Gastric bypass	12				9‖‖		1
Hall et al,[32] 1991	Upper and lower	431		445§				7
Hall et al,[33] 1996 (part A)	Upper and lower	79		76¶				5
Hall et al,[33] 1996 (part B)	Upper and lower	152				149§§		9
Heisterberg et al,[34] 1979	Gastric or biliary			49§		49¶¶		5
Joris et al,[35] 1997	Gastroplasty	10				10/10##		1
Jung et al,[36] 1980	Upper abdominal	45			36	45***		3
Lederer et al,[38] 1980	Upper abdominal	27/26/26**						5
Lindner et al,[39] 1987	Gastric or biliary		17	17‡				2
Lyager et al,[41] 1979	Gastric or biliary	43		51¶				4
O'Connor et al,[44] 1988	Cholecystectomy	20		20#				2
Ricksten et al,[46] 1986	Upper abdominal	15	13			15††		3
Schuppisser et al,[47] 1980	Upper abdominal			8#	9			3
Stock et al,[49] 1985	Upper abdominal	22	23	20‡				3
Torrington et al,[50] 1984	Gastric bypass					25/24†††		2

*References are in alphabetical order. PT = physical therapy.
†Less intensive/more intensive therapy.
‡Deep breathing and directed cough.
§Deep breathing and directed cough and postural drainage therapy.
‖Deep breathing and directed cough and postural drainage therapy and bronchodilator aerosol.
¶Deep breathing.
#Physical therapy not defined.
**Three different types of IS.
††Positive expiratory pressure mask.
‡‡Inspiratory resistance and positive expiratory pressure mask.
§§Regimen-associated IS and physical therapy.
‖‖Bilevel positive airway pressure.
¶¶Blow bottle.
##Less intensive/more intensive bilevel positive airway pressure.
***Blow glove.
†††Less intensive/more intensive regimen-associated IS, physical therapy, IPPB.
‡‡‡Data from personal communication with main author.

Table 1—*Continued*

Reported End Points						Quality Assessment			
Atelectasis	Pneumonia	Unspecified Pulmonary Complication	PaO_2/FIO_2	Vital Capacity	Length of Follow-up, d	Randomization, 0 = None; 1 = Mentioned; 2 = Described and Adequate	Concealment of Allocation, 0 = None; 1 = Yes	Observer Blinding, 0 = None; 1 = Mentioned	Follow-up, 0 = None; 1 = Incomplete; 2 = Complete
		Yes			3	1	0	0	0
	Yes		Yes		11	2	0	0	2
Yes		Yes			4	2	0	1	2
Yes	Yes	Yes	Yes	Yes	6	1	0	0	1
Yes		Yes			3	1	0	1	2
Yes	Yes		Yes		3	1	1	1	1
Yes					Hospital	1	0	1	1
		Yes	Yes	Yes	10	1	0	0	0
Yes‡‡‡	Yes‡‡‡	Yes			15	2	0	1	2
Yes	Yes				Hospital	1	0	0	0
		Yes			Hospital	2	0	0	0
Yes	Yes	Yes	Yes	Yes	4	1	0	1	0
Yes					3	1	0	0	0
Yes		Yes		Yes	5	1	0	1	0
		Yes		Yes	4	1	0	0	0
Yes	Yes	Yes	Yes	Yes	3	1	0	0	2
		Yes			3	2	0	1	1
Yes	Yes	Yes			5	1	0	1	0
				Yes	5	1	0	0	0
Yes	Yes			Yes	5	1	1	1	1
Yes	Yes	Yes		Yes	5	2	0	0	0
				Yes	3	2	1	0	2
		Yes			7	2	1	1	2
Yes	Yes	Yes			5	2	1	1	2
Yes	Yes	Yes			9	2	1	1	2
Yes					4	1	0	1	1
				Yes	3	1	0	1	2
Yes	Yes				Hospital	2	0	0	1
Yes	Yes			Yes	5	1	0	0	2
Yes	Yes	Yes		Yes	5	1	0	0	0
Yes	Yes				4	1	0	0	2
		Yes	Yes	Yes	2	1	0	0	0
Yes			Yes	Yes	3	1	0	1	2
			Yes		3	1	0	0	1
Yes	Yes			Yes	3	2	0	1	0
Yes	Yes		Yes	Yes	2	1	0	1	2

Study	Physiotherapy	N° patients with pneumonia/ Total N° patients (%) Physiotherapy	Control	Risk Difference (95%CI)	NNT (95%CI)
1 Böhner 2002[20]	CPAP	2/99 (2.0)	5/105 (4.8)	-2.8% (-8, 2)	
2 Chumillas 1998[24]	PhysTher[a]	0/40 (0)	1/41 (2.4)	-2.4% (-9, 4)	
3a Hallbook 1984[16]	PhysTher[b]	4/45 (8.9)	1/45 (2.2)	6.7% (-3, 16)	
3b Hallbook 1984[16]	PhysTher[c]	4/47 (8.5)	1/45 (2.2)	6.3% (-3, 15)	
4 Mackay 2005[42]	PhysTher[a]	1/29 (3.4)*	0/21 (0)*	3.4% (-7, 13)	
5 Morran 1983[43]	PhysTher[b]	7/51 (13.7)	19/51 (37.3)	-23.6% (-40, -7)	4.3 (2.5, 14)
6 Schwieger 86[48]	IS	0/20 (0)	1/20 (5.0)	-5.0% (-18, 8)	

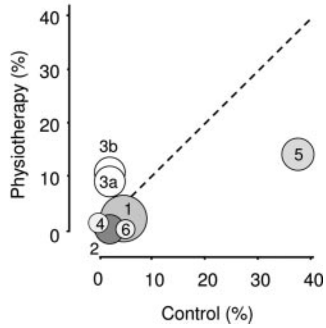

FIGURE 2. Pneumonia in trials with a no intervention control group. [a]Deep breathing and directed cough; [b]deep breathing and directed cough and postural drainage therapy; [c]deep breathing and directed cough and postural drainage therapy and bronchodilatator aerosol; *data from personal communication with main author. On the event-rate scatter, the size of the symbols is proportional to the size of the trials. NNT is displayed for statistically significant results only. PhysTher = physical therapy.

intervention control subjects reported on atelectasis (Fig 3). In two trials,[24,51] incidences of atelectasis without physiotherapy were 39% and 77%, respectively; these were significantly decreased to 15% with deep breathing and directed cough (RD, 24%; 95% CI, 5 to 43%; NNT, 4.2; 95% CI, 2.4 to 18), and to 59% with deep breathing and directed cough and postural drainage (RD, 18%; 95% CI, 5 to 31; NNT, 5.6; 95% CI, 3.3 to 19). These trials[24,51] reported a high incidence of atelectasis in control subjects; in the other studies,[16,22,31,37,42,43,48] the incidence of atelectasis in control subjects was much lower and very similar, between 20% and 25%. In four studies, IS,[22,48] IPPB,[22] and deep breathing and directed cough with or without postural drainage[22,31,43] all increased the incidence of atelectasis; differences, however, were not statistically significant.

Eight trials[19,22,24,31,40,42,45,48] (n = 743) with no intervention control subjects reported on unspecified pulmonary complications (Fig 4). Definitions varied widely and included symptoms of acute bronchitis, signs of pneumonia or atelectasis, and combinations of those; diagnoses were clinical or radiologic but never bacteriologic (Table 2). On the event-rate scatter, a large variability in incidences of unspecified pulmonary complications with active and control groups became apparent, ranging from 0 to approximately 50% (Fig 4). In a four-arm trial,[22] the incidence of unspecified pulmonary complications was significantly decreased from 47.7% without physiotherapy, to 21.4 to 22.2% with IS, deep breathing and directed cough, or IPPB; RD point estimates were 25.5 to 26.3%, and NNTs were 3.8 to 3.9. IPPB,[19] IS,[48] CPAP,[40] and deep breathing with or without directed cough[31,42,45] increased the incidence of unspecified pulmonary com-

Study	Physiotherapy	N° patients with atelectasis/ Total N° patients (%) Physiotherapy	Control	Risk Difference (95%CI)	NNT (95%CI)
1a Celli 1984[22]	IS	13/42 (30.9)	9/44 (20.4)	10.5% (-8, 29)	
1b Celli 1984[22]	PhysTher[a]	15/41 (36.6)	9/44 (20.4)	16.2% (-3, 35)	
1c Celli 1984[22]	IPPB	13/45 (28.9)	9/44 (20.4)	8.5% (-9, 26)	
2 Chumillas 1998[24]	PhysTher[a]	6/40 (15.0)	16/41 (39.0)	-24.0% (-43, -5)	4.2 (2.4, 18)
3 Giroux 1987[31]	PhysTher[a]	8/27 (29.6)	5/27 (18.5)	11.1% (-12, 34)	
4a Hallbook 1984[16]	PhysTher[b]	11/45 (24.4)	11/45 (24.4)	0% (-18, 18)	
4b Hallbook 1984[16]	PhysTher[c]	9/47 (19.1)	11/45 (24.4)	-5.3% (-22, 12)	
5 Laszlo 1973[37]	PhysTher[b]	6/12 (50.0)	9/13 (69.2)	-19.2% (-57, 19)	
6 Mackay 2005[42]	PhysTher[a]	2/21 (9.5)*	3/29 (10.3)*	-0.8% (-18, 16)	
7 Morran 1983[43]	PhysTher[b]	18/51 (35.3)	11/51 (21.6)	13.7% (-4, 31)	
8 Schwieger 1986[48]	IS	6/20 (30.0)	5/20 (25.0)	5.0% (-23, 33)	
9 Wiklander 1957[51]	PhysTher[b]	59/100 (59.0)	77/100 (77.0)	-18.0% (-31, -5)	5.6 (3.3, 19)

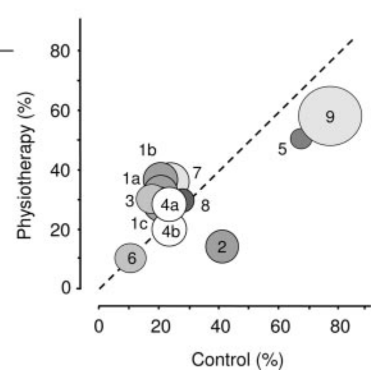

FIGURE 3. Atelectasis in trials with a no intervention control group. [a]Deep breathing and directed cough; [b]deep breathing and directed cough and postural drainage therapy; [c]deep breathing and directed cough and postural drainage therapy and bronchodilatator aerosol; *data from personal communication with main author. On the event-rate scatter, the size of the symbols is proportional to the size of the trials. NNT is displayed for statistically significant results only. See Figure 2 legend for expansion of abbreviation.

Study	Physiotherapy	N° patients with unspecified pulmonary complications/ Total N° patients (%) Physiotherapy	Control	Risk Difference (95%CI)	NNT (95%CI)
1a Baxter 1969[19]	IPPB	29/50 (58.0)	48/100 (48.0)	10.0% (-7, 27)	
1b Baxter 1969[19]	IPPB[&]	28/50 (56.0)	48/100 (48.0)	8.0% (-9, 25)	
2a Celli 1984[22]	IS	9/42 (21.4)	21/44 (47.7)	-26.3% (-46, -7)	3.8 (2.2, 14)
2b Celli 1984[22]	PhysTher[b]	9/41 (21.9)	21/44 (47.7)	-25.8% (-45, -6)	3.9 (2.2, 16)
2c Celli 1984[22]	IPPB	10/45 (22.2)	21/44 (47.7)	-25.5% (-45, -6)	3.9 (2.2, 16)
3 Chumillas 1998[24]	PhysTher[b]	3/40 (7.5)	8/41 (19.5)	-12.0% (-27, 3)	
4 Giroux 1987[31]	PhysTher[b]	1/27 (3.7)	0/27 (0)	3.7% (-6, 13)	
5 Lotz 1984[40]	CPAP	1/32 (3.1)	0/32 (0)	3.1% (-5, 11)	
6 Mackay 2005[42]	PhysTher[b]	5/29 (17.2)	3/21 (14.3)	3.1% (-17, 23)	
7 Palmer 1952[45]	PhysTher[a]	8/40 (20.0)	5/42 (11.9)	8.1% (-8, 24)	
8 Schwieger 1986[48]	IS	8/20 (40.0)	6/20 (30.0)	10.0% (-19, 39)	

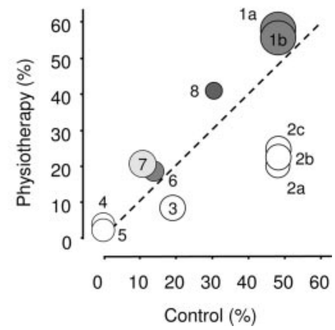

FIGURE 4. Unspecified pulmonary complications in trials with a no intervention control group. [a]Deep breathing; [b]deep breathing and directed cough; [&]more intensive therapy. On the event-rate scatter, the size of the symbols is proportional to the size of the trials. NNT is displayed for statistically significant results only. See Figure 2 legend for expansion of abbreviation.

plications in one study each; differences, however, were not statistically significant.

Five trials[16,20,24,40,48] (n = 526) had a no intervention control group and reported PaO_2/FIO_2 ratios (Table 3). Values varied from 255 to 381 mm Hg; no significant differences were reported.

Three trials[24,40,48] (n = 185) had a no intervention control group and reported on vital capacity (Table 4). Values varied from 2,120 to 2,816 mL; no significant differences were reported.

Active Intervention vs Active Intervention (Without No Intervention Control Subjects)

Twenty-two trials[18,21,23,25–30,32–36,38,39,41,44,46,47,49,50] (n = 2,734) compared 15 different methods of phys-

Table 2—*Unspecified Pulmonary Complications in Trials With a No Intervention Control Group*

Study	Definition	Criteria: Clinical	Radiologic	Bacteriologic
Baxter and Levine,[19] 1969	Atelectasis and pneumonia	Yes	Yes	
Celli et al,[22] 1984	Acute bronchitis	Yes		
Chumillas et al,[24] 1998	Atelectasis, pneumonia, and acute bronchitis	Yes	Yes	
Giroux et al,[31] 1987	Atelectasis and acute bronchitis	Yes	Yes	
Lotz et al,[40] 1984	Acute bronchitis	Yes		
Mackay et al,[42] 2005	Atelectasis, pneumonia, and acute bronchitis	Yes	Yes	
Palmer and Sellick,[45] 1952	Atelectasis and pneumonia	Yes	Yes	
Schwieger et al,[48] 1986	Atelectasis and pneumonia	Yes	Yes	

Table 3—*PaO_2/FIO_2 in Trials With a No Intervention Control Group**

Study	PaO_2/FIO_2, mm Hg: IS	CPAP	Physical Therapy	No Intervention
Böhner et al,[20] 2002		255 ± 94		269 ± 122
Chumillas et al,[24] 1998			364†‡	360†
Hallbook et al,[16] 1984			380 ± 78§/347 ± 66‖	381 ± 63
Lotz et al,[40] 1984		343 ± 33		343 ± 33
Schwieger et al,[48] 1986	343 ± 19			357 ± 52

*Data are presented as mean ± SD. No statistical differences were reported.
†SD not available.
‡Deep breathing and directed cough.
§Deep breathing and directed cough and postural drainage therapy.
‖Deep breathing and directed cough and postural drainage therapy and bronchodilatator aerosol.

Table 4—*Vital Capacity in Trials With a No Intervention Control Group**

Study	Vital Capacity, mL			
	IS	CPAP	Physical Therapy	No Intervention
Chumillas et al,[24] 1998			66†‡	71†
Lotz et al,[40] 1984		2,816 ± 640		2,480 ± 340
Schwieger et al,[48] 1986	2,280 ± 750			2,120 ± 950

*Data are presented as mean ± SD unless otherwise indicated.
†Data presented as % of preoperative volume.
‡Deep breathing and directed cough.

iotherapy without a no intervention control group (Tables 5–9). There were no significant differences in the incidence of pneumonia (Table 5) or atelectasis (Table 6).

Significant results were reported in five studies.[26,30,35,39,46] There were fewer unspecified pulmonary complications with IS compared with a not-well-defined physical therapy (Table 7).[26] There was a better PaO_2/FIO_2 ratio with a positive expiratory pressure mask compared with CPAP, and both interventions were more efficacious than IS (Table 8).[46] Finally, four studies reported on significant differences in vital capacity values in favor of different physiotherapy treatments (Table 9): bilevel positive airway pressure was better than IS,[30,35] positive expiratory pressure mask and CPAP were more efficacious than IS,[46] and CPAP was more efficacious than deep breathing with directed cough and postural drainage therapy.[39]

Table 5—*Incidence of Pneumonia in Trials Without a No Intervention Control Group**

Study	IS	CPAP	Physical Therapy	IPPB	Others
Christensen et al,[23] 1991			29§		35**/6††
Craven et al,[26] 1974	29		43‖		
Denehy et al,[28] 2001		11/6‡	22¶		
Dohi and Gold,[29] 1978	12			23	
Hall et al,[33] 1996 (part A)	0		0#		
Hall et al,[33] 1996 (part B)	3				1‡‡
Jung et al,[36] 1980	11			0	2§§
Lederer et al,[38] 1980	0/0/4†				
Lindner et al,[39] 1987		6	6¶		
Lyager et al,[41] 1979	5		2#		
Stock et al,[49] 1985	5	0	5¶		
Torrington et al,[50] 1984					8/4‖‖

*Data are presented as %.
†Three different types of IS.
‡Less intensive/more intensive therapy.
§Deep breathing and directed cough and postural drainage therapy.
‖Physical therapy not defined.
¶Deep breathing and directed cough.
#Deep breathing.
**Positive expiratory pressure mask.
††Inspiratory resistance and positive expiratory pressure mask.
‡‡Regimen-associated IS and physical therapy.
§§Blow glove.
‖‖Less intensive/more intensive association of IS, physical therapy, and IPPB.

Adverse Effects

In two trials,[30,35] 3 of 20 patients (15%) and 4 of 14 patients (29%), respectively, did not tolerate bilevel positive airway pressure due to discomfort. In one study,[20] 9 of 99 patients (9%) did not tolerate CPAP for > 12 h due to claustrophobia, and 4 of 99 patients (4%) had superficial nose ulcers.[20] Abdominal distension occurred in 8 of 45 patients (18%) treated with IPPB.[22] Finally, in one study,[32] an incision hernia developed in 1 of 445 patients during chest physiotherapy. Twenty-six trials[16,18,19,21,25–29,31,33,34,36–41,43–45,47–51] did not mention any adverse effects, and 4 trials[23,24,42,46] reported that none had occurred.

Conclusions of the Original Investigators

Authors of 4 of the 13 trials with no intervention control subjects concluded that prophylactic respiratory physiotherapy after abdominal surgery was useful; 1 trial each reported on a significant effect on atelectasis,[24,51] pneumonia,[43] or unspecified pulmonary complications.[22] Authors of 5 of the 22 active-controlled trials[26,30,35,39,46] concluded that one of the tested interventions was superior.

Discussion

Six of 13 trials[16,20,24,42,43,48] with a no intervention control group, the most valid trial design in this context, reported on the clinically most relevant end point, pneumonia. Only one of these trials[43] showed a beneficial effect of physiotherapy on pneumonia. In that trial, the incidence of pneumonia in control subjects was extraordinarily high, challenging external validity of these data. Thus, the usefulness of prophylactic respiratory physiotherapy for the prevention of clinically relevant postoperative pulmonary complications after abdominal surgery remains unproven.

Table 6—*Incidence of Atelectasis in Trials Without a No Intervention Control Group**

Study	IS	CPAP	Physical Therapy	IPPB	Others
Ali et al,[18] 1984			13‖	7	
Christensen et al,[23] 1991			53‖		65††/53‡‡
Craven et al,[26] 1974	11		20¶		
Denehy et al,[28] 2001		60/57§	88#		
Dohi and Gold,[29] 1978	15			23	
Hall et al,[33] 1996 (part A)	8		11**		
Hall et al,[33] 1996 (part B)	16				13§§
Heisterberg et al,[34] 1979			31‖		31‖‖
Jung et al,[36] 1980	49			36	36¶¶
Lederer et al,[38] 1980	0/8/0†				
Lindner et al,[39] 1987		0	24#		
Lyager et al,[41] 1979	58		37**		
Ricksten et al,[46] 1986	80	69			40††
	40‡,***	8‡,***			0††,‡,***
Stock et al,[49] 1985	41	23	42#		
Torrington et al,[50] 1984					32/33##

*Data are presented as %.
†Three different types of IS.
‡Incidence of major atelectasis.
§Less intensive/more intensive therapy.
‖Deep breathing and directed cough and postural drainage therapy.
¶Physical therapy not defined.
#Deep breathing and directed cough.
**Deep breathing.
††Positive expiratory pressure mask.
‡‡Inspiratory resistance and positive expiratory pressure mask.
§§Regimen-associated IS and physical therapy.
‖‖Blow bottle.
¶¶Blow glove.
##Less intensive/more intensive association of IS, physical therapy, and IPPB.
***Statistically significant differences between interventions.

Most investigators preferred to report on vital capacity, PaO_2/FIO_2 ratios, atelectasis, or unspecified pulmonary complications. The significance of vital capacity and PaO_2/FIO_2 ratios are unclear; they may be regarded as surrogate end points, and there was actually no evidence of any improvement in these parameters with any of the tested physiotherapy treatments. The main problem with the end points "atelectasis" or "unspecified pulmonary complications" was the lack of a clear and universally accepted definition. And, as for vital capacity and PaO_2/FIO_2 ratios, there was uncertainty about the clinical relevance of these outcomes. For instance, "unspecified pulmonary complications" is a composite end point that includes diverse pathologies such as bronchitis, pneumonia, or atelectasis. Perhaps as a consequence of the variability in definitions of unspecified pulmonary complications, control event rates varied widely, ranging from 0% to almost 50%. Composite outcomes are appropriate only when the individual symptoms are well defined, when the components are of equal importance, and occur with similar frequencies, and when the active intervention leads to a similar relative risk reduction of all components.[55] This is not the case for unspecified pulmonary complications. A metaanalysis[7] reported a positive impact of prophylactic respiratory physiotherapy after abdominal surgery; interestingly, that favorable result was based exclusively on the analysis of unspecified pulmonary complications.

Our analysis has some limitations; most are related to weaknesses in the original studies. For instance, these trials were of limited methodologic quality; in less than half, observers were blinded; one third only reported on details of randomization and follow-up; and in a minority, treatment allocation was concealed. One inherent problem of physiotherapy trials is that the observer only can be blinded. We do not know whether the trials were badly designed or the data inadequately reported; most were published before the first Consolidated Standards of Reporting Trials statement.[56] The problem is that trials of low methodologic quality may exaggerate estimates of efficacy.[57] Many trials were of limited size. Small trial size may partly explain the variability in event rates. Also, small trials may be associated with low statistical power to detect statistically significant effects, even if true effects exist. Moreover, small

Table 7—*Incidence of Unspecified Pulmonary Complications in Trials Without a No Intervention Control Group**

Study	IS	CPAP	Physical Therapy	IPPB	Others	Definition	Criteria: Clinical	Radiologic	Bacteriologic
Ali et al,[18] 1984			13†	7		Atelectasis and pneumonia	Yes	Yes	
Campbell et al,[21] 1986			31‡		22#	Atelectasis and pneumonia	Yes	Yes	Yes
Christensen et al,[23] 1991			71†		76#/65**	Atelectasis, pneumonia, and acute bronchitis	Yes	Yes	
Condie et al,[25] 1993			8/3‡§			Acute bronchitis	Yes		
Craven et al,[26] 1974	46‡‡		71‖,‡‡			Atelectasis, pneumonia, and acute bronchitis	Yes	Yes	
Dohi and Gold,[29] 1978	29			57		Atelectasis, pneumonia, and acute bronchitis	Yes	Yes	
Hall et al,[32] 1991	16		15†			Atelectasis and pneumonia	Yes	Yes	Yes
Hall et al,[33] 1996 (part A)	8		11¶			Atelectasis and pneumonia	Yes	Yes	Yes
Hall et al,[33] 1996 (part B)	19				13††	Atelectasis and pneumonia	Yes	Yes	Yes
Lindner et al,[39] 1987		6	29‡			Atelectasis and acute bronchitis	Yes	Yes	
O'Connor et al,[44] 1988	25		45‖			Acute bronchitis	Yes		

*Data are presented as %.
†Deep breathing and directed cough and postural drainage therapy.
‡Deep breathing and directed cough.
§Less intensive/more intensive therapy.
‖Physical therapy not defined.
¶Deep breathing.
#Positive expiratory pressure mask.
**Inspiratory resistance and positive expiratory pressure mask.
††Regimen-associated IS and physical therapy.
‡‡Statistically significant differences between interventions.

trials are less likely to identify rare events, for instance, intervention-related adverse effects. Twenty-four of the 31 trials did not mention any adverse effects; however, not reporting of adverse effects does not mean that none had occurred. Most adverse effects were minor and we may assume that they are preventable through adequate handling of devices and appropriate training of chest therapists. Yet, the combination of potential for harm and doubtful efficacy further challenges the usefulness of routine prophylactic respiratory physiotherapy in these patients. Finally, as in similar previous analyses,[9] a large variety of physiotherapy regimens were tested. This variability suggests that there is no consensus among physiotherapists on how to use these therapies and of what the "gold standard" intervention consists. In the absence of a "gold standard," trials should be designed to include a placebo group or, in this case, a no intervention control group.[58] A minority only of the retrieved trials fulfilled that criterion. Finally, we had to assume that patients were treated in upright position and that they were mobilized, although this

Table 8—*PaO_2/FIO_2 Ratio in Trials Without a No Intervention Control Group**

Study	PaO_2/FIO_2 Ratio, mm Hg: IS	CPAP	Physical Therapy	IPPB	Others
Christensen et al,[23] 1991			291‡§		295‡¶/312‡#
O'Connor et al,[44] 1988	332 ± 82		332 ± 43‖		
Ricksten et al,[46] 1986	315 ± 58†	369 ± 48†			398 ± 40†¶
Schuppisser et al,[47] 1980			314‡‖	333‡	
Torrington et al,[50] 1984					280‡/277‡,**

*Data are presented as mean ± SD.
†Statistically significant differences between interventions.
‡SD not available.
§Deep breathing and directed cough and postural drainage therapy.
‖Physical therapy not defined.
¶Positive expiratory pressure mask.
#Inspiratory resistance and positive expiratory pressure mask.
**Less intensive/more intensive association of IS, physical therapy, and IPPB.

Table 9—*Vital Capacity in Trials Without a No Intervention Control Group**

Study	Vital Capacity, mL				
	IS	CPAP	Physical Therapy	IPPB	Others
Ali et al,[18] 1984			80§‖	74§	
Campbell et al,[21] 1986			2,429 ± 918¶		2,281 ± 670††
Christensen et al,[23] 1991			1,750‡‖		2,000‡††/1,900‡,‡‡
Crawford et al,[27] 1990			2,570 ± 750#		2,870 ± 670##
Denehy et al,[28] 2001		83/77§	87§¶		
Dohi and Gold,[29] 1978	2,700 ± 500			2,400 ± 600	
Ebeo et al,[30] 2002	2,034 ± 339†				2,512 ± 290†§§
Joris et al,[35] 1997	1,445 ± 275†				1,528 ± 492/2,190 ± 555†‖‖
Lederer et al,[38] 1980	1,477/1,709/1,468‡**				
Lindner et al,[39] 1987		3,100†‡	2,100†‡‖		
O'Connor et al,[44] 1988	2,150 ± 920		1,640 ± 720#		
Ricksten et al,[46] 1986	1,850 ± 658†	2,550 ± 900†			2,700 ± 1,161†,††
Stock et al,[49] 1985	2,057 ± 1,258	2,007 ± 653	2,378 ± 898¶		
Torrington et al,[50] 1984					2,170‡/2,000‡¶¶

*Data are presented as mean ± SD unless otherwise indicated.
†Statistically significant differences between interventions.
‡SD not available.
§Data presented as % of predicted value.
‖Deep breathing and directed cough and postural drainage therapy.
¶Deep breathing and directed cough.
#Physical therapy not defined.
**Three different types of IS.
††Positive expiratory pressure mask.
‡‡Inspiratory resistance and positive expiratory pressure mask.
§§Bilevel positive airway pressure.
‖‖Less intensive/more intensive bilevel positive airway pressure.
¶¶Less intensive/more intensive association of IS, physical therapy, and IPPB.
##Regimen-associated IS and physical therapy.

was not specified in the original trials. The necessary information to perform subgroup analyses to estimate the impact of such measurements on the efficacy of physiotherapy treatments was lacking.

What are the implications of this analysis? There are clinical settings, in which the usefulness of respiratory physiotherapy is based on strong evidence, for instance, therapeutic noninvasive positive pressure ventilation in patients with acute exacerbations of severe COPD,[59,60] pulmonary rehabilitation in patients with COPD,[61,62] chest physical therapy in patients with cystic fibrosis,[63] or CPAP for the treatment of postoperative hypoxemia.[64] Yet, considering the available evidence, routine use of prophylactic respiratory physiotherapy in patients after abdominal surgery does not seem to be justified. These trials were published between 1952 and 2005, they tested a large variety of physiotherapy treatments after different abdominal surgeries, and the majority of the studies were of only limited methodologic quality. It is, therefore, difficult to draw specific conclusions. For deep breathing with directed cough, the only method that showed some efficacy, we have to assume that the positive results were biased by trials that reported on very high control event rates or end points with doubtful clinical relevance.

The agenda is one of further research rather than of clinical recommendations. With > 4 million abdominal surgeries performed each year in the United States alone,[1] it is of economic importance whether a labor-intensive and thus costly intervention with doubtful efficacy is routinely performed. Thus, the usefulness of prophylactic respiratory physiotherapy after abdominal surgery needs to be established in valid clinical trials before this intervention can be recommended for routine use. To avoid methodologic pitfalls in future studies, some issues that have been identified through this systematic review need to be addressed. All patients randomized to the experimental group should be treated with an identical technique of physiotherapy, including similar frequency and duration, and administered by trained physiotherapists. In all patients, further procedures, such as analgesia or mobilization, should also be identical. Trials should be of reasonable size to overcome random variations, and to identify with confidence small but clinically relevant benefits and rare adverse effects. Perhaps the most important potential benefit of respiratory physiotherapy, both from a clinical and the patient's point of view, is the prevention of pneumonia. This end point needs a clear definition; the most appropriate in the context of nosocomial pneumonia may be from the Centers for Disease Control and Prevention.[65] When ever feasible, assessments should be done by observers who are unaware of treatment allocation. The observation period should be expanded until hospital discharge. Length of stay (in the ICU and in the hospital) has important implications for costs; these data should be reported. Pulmonary high-risk patients need to be included in future trials. Risk scores, such as the multifactorial risk index for predicting postoperative respiratory failure in patients undergoing major noncardiac surgery,[66,67] may be used to stratify patients to those who are most likely to profit from prophylactic respiratory physiotherapy.

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