Review article

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Postoperative conditions of rehabilitative interest in lung transplantation: a systematic review

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Lung transplantation is an elective treatment option for end-stage respiratory diseases in which all medical therapy options have been exhausted. The current study aimed to identify updated information on the postoperative conditions that may impair rehabilitation after lung transplantation and to provide specific considerations of their clinical relevance during the recovery process. The present study is a systematic review conducted by searching three primary databases: the United States National Library of Medicine PubMed system, Scopus, and the Cochrane Library. The databases were searched for articles published from database inception until May 2024; at the end of the selection process, 27 documents were included in the final analysis. The retrieved material identified 19 conditions of rehabilitative interest that potentially affect the postoperative course: graft dysfunction, dysphagia, postsurgical pain, cognitive impairment, chronic lung allograft dysfunction-bronchiolitis obliterans syndrome, phrenic nerve injury, delayed extracorporeal membrane oxygenation weaning, airway clearance, refractory hypoxemia, mediastinitis, reduced oxidative capacity, sternal dehiscence, coronavirus disease 2019 (COVID-19), gastroparesis, ossification of the elbow, Takotsubo cardiomyopathy, airway dehiscence, recurrent pleural effusion, and scapular prolapse. Although some patients are not amenable to rehabilitation techniques, others can significantly improve with rehabilitation.

Keywords: Lung transplantation; Physiotherapy; Postoperative complications; Rehabilitation; Systematic review; Treatment outcome

Introduction

Lung transplantation (LT) is an elective treatment option for end-stage respiratory diseases in which all medical therapy options have been exhausted [1-18]. At the same time, advances in technical aspects, such as the use of extracorporeal membrane oxygenation (ECMO) as a bridge to transplantation, have improved the possibility of LT by supporting the recipient pool and allowing safe rehabilitation and optimization of care [19-27].

Since the initial experiences with LT dating back to the 1970s, rehabilitation has been recognized as a cornerstone of the recovery pathway after LT. An increasing amount of data has been published supporting the principle that rehabilitation should be provided be-

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fore and after LT to optimize physical performance preoperatively [28-30] and enhance functional recovery postoperatively [30-36]. Although immunosuppressive therapy has drastically increased the survival rates of patients undergoing solid organ transplantation and has allowed stable clinical outcomes, acute rejection may occur frequently together with viral and fungal infections after LT [37,38]. Contextually, the postoperative course could be impeded by other conditions such as ischemic reperfusion injury; neurological complications (stroke, severe toxic/metabolic encephalopathy); airway complications (dehiscence and stenosis); renal complications sustained by the nephrotoxicity of calcineurin inhibitors resulting in acute tubular necrosis and renal failure; hypertension, diabetes and hyperlipidemia as side effects of calcineurin inhibitors and steroid administration; osteoporosis resulting from preoperative diminished mobility and corticosteroid therapy; cutaneous complications; hematological complications such as leucopenia, anemia and thrombocytopenia; and diaphragmatic palsy resulting from intraoperative phrenic nerve injury [37,39-45]. Previous studies have highlighted that postoperative complications after LT can involve different body systems with musculoskeletal, neurological, cardiovascular, respiratory, and infectious manifestations [46].

Although the postoperative complications of LT have been widely discussed in the literature, there is currently no special focus on further conditions from the perspective of rehabilitation. The current study aimed to identify updated information on the postoperative conditions that may impair rehabilitation after LT and provide specific considerations of their clinical relevance during the recovery pathway.

Study design

The present study is a systematic review conducted by searching three primary databases: the United States National Library of Medicine PubMed system, Scopus, and the Cochrane Library. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were used to design this review [47]. The databases were searched for articles published from database inception until May 2024. Four keyword entries, "lung transplantation," "postoperative complications," "rehabilitation," and "physiotherapy" were matched into two search strings using the Boolean operators AND and OR (Table 1). In each database, the following fields were searched: PubMed (all fields); Scopus and the Cochrane Library (title, abstract, and keywords). No filters were applied for the document type, age, sex, publication date, language, or subject.

Inclusion and exclusion criteria

To be included, citations had to be published in English and describe postoperative complications of rehabilitative interest in adult patients undergoing LT. Conversely, citations not describing postoperative sequelae, those including individuals aged < 18 years, and those published in languages other than English were not eligible for inclusion.

After removing duplicates, the remaining documents were screened for eligibility based on their abstracts. For articles with abstracts that met the inclusion criteria, full texts were also screened for suitability, and confirmed citations were considered eligible for the final analysis. The search was completed on May 31, 2024.

Results

The initial search returned 391 articles, and after removal of duplicates, 334 citations were screened. At the end of the selection process, 27 documents were included in the final analysis (Fig. 1). Fifteen of the 27 articles were observational studies [48-62], seven were case reports [63-69], four were case series [70-73], and one was a randomized controlled trial [74] (Table 2). Eleven of the 27 studies were conducted in the United States, nine in Europe, three

Table 1. Search strings and keywords used in the selected databases

Database	Search string
PubMed	("lung transplantation"[MeSH Terms] OR ("lung"[All Fields] AND "transplantation"[All Fields]) OR "lung transplantation"[All Fields] OR ("lung"[All Fields] AND "transplant"[All Fields]) OR "lung transplant"[All Fields]) AND ("postoperative complications"[MeSH Terms] OR ("postoperative"[All Fields] AND "complications"[All Fields]) OR "postoperative complications"[All Fields]) AND ("rehabilitant"[All Fields] OR "rehabilitants"[All Fields] OR "rehabilitate"[All Fields] OR "rehabilitated"[All Fields] OR "rehabilitates"[All Fields] OR "rehabilitating"[All Fields] OR "rehabilitation"[MeSH Terms] OR "rehabilitation"[All Fields] OR "rehabilitations"[All Fields] OR "rehabilitative"[All Fields] OR "rehabilitation"[MeSH Subheading] OR "rehabilitation s"[All Fields] OR "rehabilitational"[All Fields] OR "rehabilitator"[All Fields] OR "rehabilitators"[All Fields] OR ("physical therapy modalities"[MeSH Terms] OR ("physical"[All Fields] AND "therapy"[All Fields] AND "modalities"[All Fields]) OR "physical therapy modalities"[All Fields] OR "physiotherapies"[All Fields] OR "physiotherapy"[All Fields]))
Scopus	(TITLE-ABS-KEY (lung AND transplantation) AND TITLE-ABS-KEY (postoperative AND complications) AND TITLE-ABS-KEY (rehabilitation) OR TITLE-ABS-KEY (physiotherapy))
Cochrane Library	Title Abstract Keywords (lung transplantation AND postoperative complications) AND Title Abstract Keywords (rehabilitation OR physiotherapy)

in Australia, three in China, and one in Canada. There were 1,580 patients (Fig. 2), of whom 878 (56%) were men (Table 2). The type of LT was not available in all of the included studies; therefore, it was possible to identify 909 double LTs, 311 single LTs, and four heart-lung transplants. The retrieved articles identified 19 conditions (Fig. 3) of rehabilitative interest potentially impacting the postoperative course (Tables 2, 3).

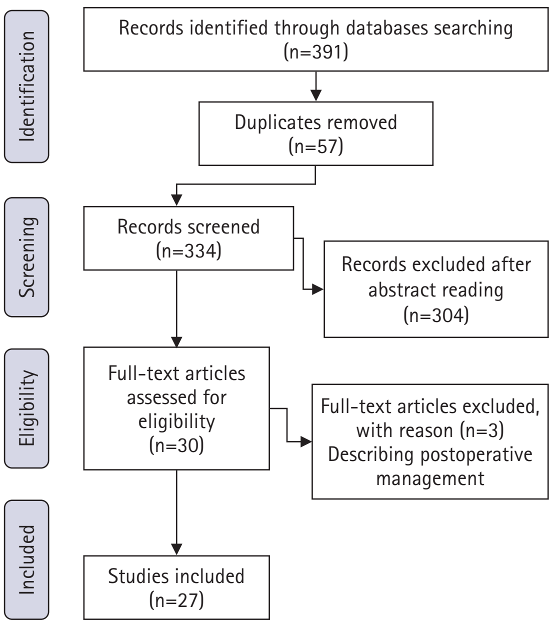

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart.

Conditions impacting postoperative rehabilitation in lung transplantation recipients

After LT, rehabilitation commences in the intensive care unit (ICU) and proceeds along the recovery pathway [36,75,76]. Patients should participate in rehabilitation programs in order to guarantee and enhance postoperative outcomes [77]. LT is associated with complications, including postoperative vascular, neurological, and respiratory issues that could develop postoperatively [37,78-80]. Among the postoperative complications, there are heterogeneous conditions of rehabilitative interest that potentially impact the postoperative course and can complicate different clinical domains involving cognitive, motor, and respiratory functions (Tables 2, 3).

1. Graft dysfunction

Primary graft dysfunction (PGD) remains a leading cause of 90-day and 1-year mortality in LT recipients and is classified into three stages, with PGD grade 3 characterized by partial pressure of oxygen (PaO_2)/fraction of inspired oxygen (FiO_2) < 200 mmHg, plus

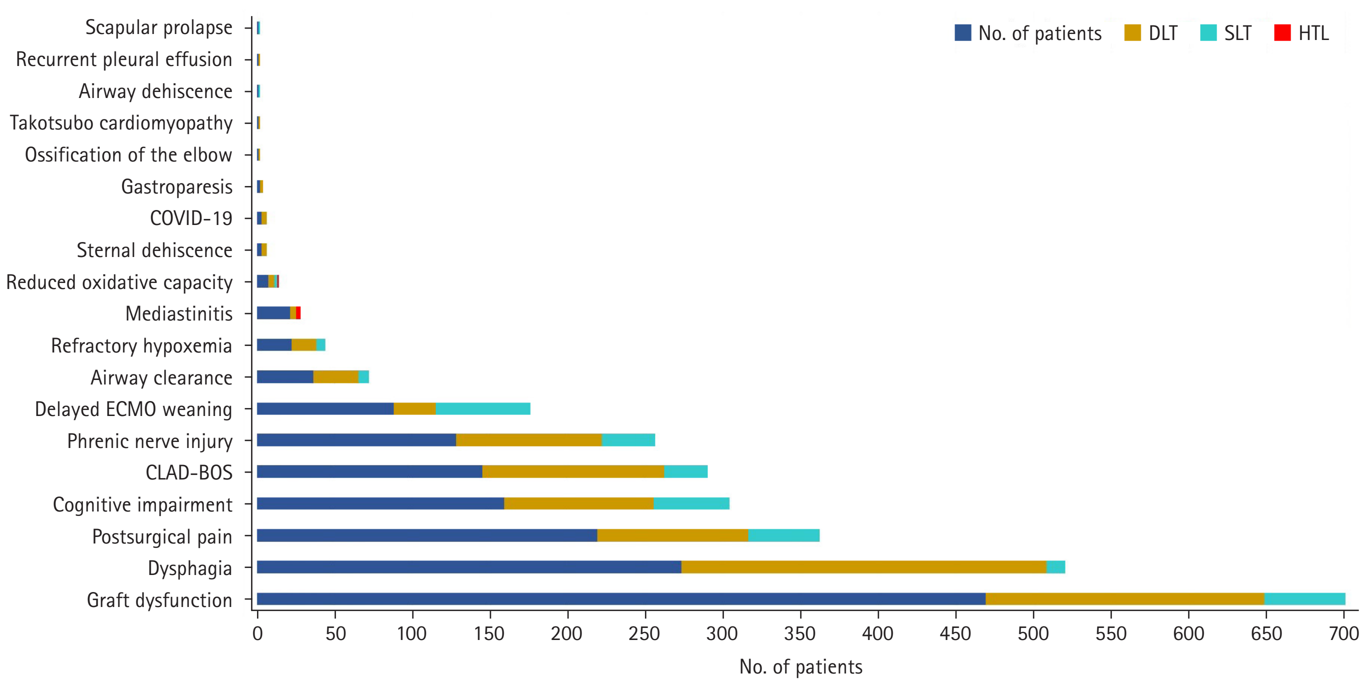

Fig. 2. Conditions of rehabilitative interest and number of patients. DLT, double lung transplant; SLT, single lung transplant; HLT, heart-lung transplant; COVID-19, coronavirus disease 2019; ECMO, extracorporeal membrane oxygenation; CLAD-BOS, chronic lung allograft dysfunction-bronchiolitis obliterans syndrome.

Table 2. Characteristics of the included studies

Study	Year	Country	Study design	Patients	No. of males (%)
Yu et al. [48]	2023	Canada	Retrospective	140 patients with a mean age of 47.2 ± 13.6 years underwent solid organ transplantation; of these, 64 were LT (61 DLT, 3 SLT). Patients were monitored for opioid consumption. Pain was evaluated at pretransplant visit, 15 ± 11 days posttransplant, 29 ± 11 days after the first follow-up, and 210 ± 636 days after the first follow-up. Patients were offered to enroll in a physiotherapy consultation to manage postsurgical pain	80 (57)
Wildgaard et al. [49]	2010	Denmark	Cross-sectional (survey)	79 patients (46% DLT) with a mean age of 50 years (IQR 21–69 years) were invited to complete a questionnaire and describe their pain perception at a mean follow-up of 39 months after surgery	36 (46)
Li et al. [50]	2023	China	Comparative	88 LT recipients were allocated into two groups; 41 aged 54 years (IQR 50–64 years) were immediately weaned from VV-ECMO after LT, and 47 aged 60 years (IQR 49.5–64.5 years) had delayed weaning	78 (89)
Dallal-York et al. [51]	2022	USA	Retrospective	205 patients with a mean age of 58.6 ± 13.7 years undergoing LT executed posttransplant VFSE to assess swallowing safety. 170 patients aged 59.8 ± 12.4 years out of 205 underwent pretransplant VFSE	104 (51)
Black et al. [52]	2019	Australia	Cross-sectional	68 patients with a mean age of 48.3 ± 13 years were referred to speech pathology consultation; 67 out of 68 underwent evaluation of voice	40 (59)
Hernández-Hernández et al. [53]	2022	Spain	Prospective	127 LT recipients aged 59 years (IQR 53–62 years) were assessed for phrenic nerve injury by diaphragm ultrasound examination and phrenic nerve conduction. Diaphragm ultrasound and phrenic nerve conduction studies were performed 3 days (IQR 2–6 days) days and 18 days (IQR 8–21 days) after LT	89 (70)
Cohen et al. [54]	2014	USA	Retrospective	56 patients, 14 LT candidates with a median age of 60 years (IQR 56–65 years), and 42 LT recipients aged 60 years (IQR 57–64 years) were screened to examine cognition using the MoCA	24 (43)
Tomasi et al. [55]	2022	Germany	Prospective	24 patients were allocated into two groups: 14 with a median age of 55 years (IQR 20.5–59 years) in the POCD group and 10 aged 59 years (45.5–65 years) in the non-POCD group to evaluate the postoperative cognitive function using a battery of neuropsychological tests (VVLT, SCWT, CST)	8 (33)
Cao et al. [56]	2024	China	Cross-sectional (survey)	79 patients with a mean age of 51.6 ± 14.5 years returned a questionnaire investigating POCD by using the MoCA at four time points: 8 days, 1 month, 3 months, and 6 months after surgery	63 (80)
Armstrong et al. [57]	2016	USA	Retrospective	243 LT recipients with a median age of 56 years (IQR 42–62 years) were assessed to compare the long-term functional outcomes of those who developed grade 3 PGD with those who did not	119 (49)
Kolaitis et al. [58]	2021	USA	Prospective	226 LT recipients with a mean age of 55.7 ± 12.6 years were assessed to test whether PGD was associated with increased disability (LT-VLA scale), depression (GDS), and poorer HRQL (SF12-PCS and SF12-MCS)	125 (55)
Riera et al. [59]	2017	Spain	Prospective	22 LT recipients with a median age of 58 years (IQR 53–62 years) out of 131 (16.8%) received prone positioning because of postoperative refractory hypoxemia with the need for a FiO_2 > 0.7 for a PaO_2 > 80 mmHg. Prone positioning was stopped when PaO_2/FiO_2 > 150 mmHg, with a FiO_2 < 0.6, and when improvement was maintained for at least 4 hours in the supine position	15 (68)
van Den Berg et al. [60]	2000	Netherlands	Cross-sectional	116 LT recipients were evaluated postoperatively to define the incidence of CLAD-BOS. Patients were allocated into two groups: (1) LT recipients not developing CLAD-BOS were 64 with a mean age of 43 ± 12 years, and (2) LT recipients developing CLAD-BOS were 52 with a mean age of 42 ± 13 years	35 (41)
Vermeulen et al. [61]	2004	Netherlands	Observational	The study cohort comprised 29 LT recipients with a mean age of 45 years (IQR 21–52 years) who completed the follow-ups and returned the questionnaires for assessing HRQL	18 (62)
Abid et al. [62]	2003	UK	Retrospective	21 patients with a mean age of 42.8 ± 15.1 years developed mediastinitis (presence of pus or bacterial growth, or both, in mediastinal tissue either with or without sternal instability) posttransplant, of these, 3 were HLT and 4 DLT	18 (86)
Xu et al. [63]	2018	China	Case report	A 44-year-old woman LT recipient suffered failed weaning from MV on POD 3 and was evaluated with diaphragm electromyography. The TwPdi measurements under magnetic stimulation of the phrenic nerves showed a bilateral PNCT of 13 milliseconds and bilateral diaphragmatic CMAPs of 0.508 mV	0 (0)
Munin et al. [64]	1995	USA	Case report	A 37-year-old woman received a DLT and, on POD 18, presented with reduced ROM in both elbows. X-ray examination showed bilateral heterotopic ossification along the posterior humerus and ulna. The patient underwent right elbow osteotomy resection of the heterotopic ossification and anterior ulnar nerve transposition	0 (0)
Keller et al. [65]	2020	USA	Case report	A 68-year-old woman underwent DLT and, on POD 9, tested positive for COVID-19 after having developed worsening hypoxemia with extensive pulmonary edema consistent with grade 3 PGD. On POD 14, the test was negative, and on POD 30, the patient underwent a tracheostomy	0 (0)

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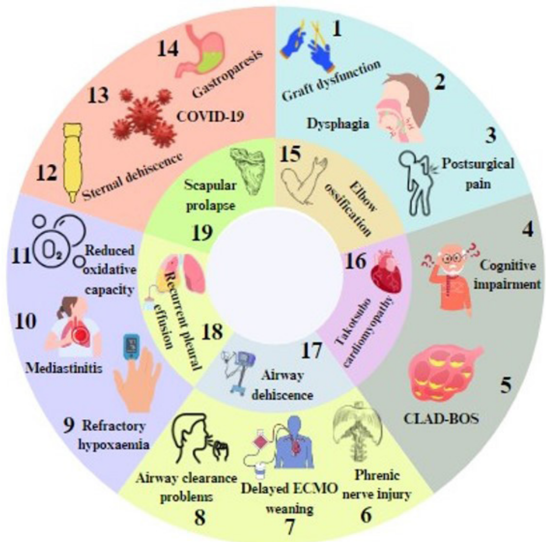
Table 2. Continued

Study	Year	Country	Study design	Patients	No. of males (%)
Duclos et al. [66]	2018	France	Case report	A 50-year-old man underwent DLT and had cardiac arrest during induction; transesophageal echocardiography showed global hyperkinetic left ventricular function with supranormal cardiac output, no regional hypokinesia of the left ventricle, and no obstruction or dilatation of the right ventricle	1 (100)
Backer et al. [67]	2020	USA	Case report	A 66-year-old man SLT recipient with comorbidities developed a fungal empyema and partial dehiscence of the right anastomosis; in addition, he had exertional dyspnea and required oxygen supplementation (2 L/min). Surgery to treat airway dehiscence was not considered a viable option because of the complicated postoperative course, infected pleural space, and physical deconditioning. The dehiscence was then treated by applying thermal energy around the edge to promote neoepithelialization	1 (100)
Panchabhai et al. [68]	2015	USA	Case report	A 29-year-old woman DLT recipient underwent retransplantation because of CLAD-BOS 6 years after the first LT. The patient was weaned from MV and started physical rehabilitation. After 2 weeks, the patient presented with hypoxemia and right pleural effusion (600 mL). Because of persistent pleural fluid accumulation tube thoracostomy was placed with the evacuation of 1,200 mL of milky white fluid. Pleural fluid cultures grew *Candida glabarata*, *Burkholderia cepacia*, and *Enterococcus fecium*. Given the polymicrobial growth of the pleural fluid culture with organisms similar to the patient's sinus culture and enteric sources, esophageal perforation was suspected and confirmed by an exploratory thoracotomy	0 (0)
Chansakul et al. [69]	2014	USA	Case report	A 76-year-old woman SLT recipient, and 8 months after LT, the patient presented with shoulder pain which radiated down her back and she was unable to lift her arm overhead. Pain on more than 30° of forward flexion and 30° abduction of the right shoulder was present. CT scan showed an abnormal position of the right scapula, with the inferior angle of the scapula protruding into the right intrathoracic cavity	0 (0)
Orsini et al. [70]	2014	France	Case series	3 DLT recipients (mean age 47.7 ± 9 years) out of 61 developed sternal dehiscence 2–3 months after surgery	2 (67)
Weinkauf et al. [71]	2005	USA	Case series	Twp DLT recipients with a mean age of 40 years (IQR 26–54 years) developed postoperative gastroparesis (delayed passage of gastric contents into the intestine) and were treated with TENS at 18 months and 8 months after surgery, respectively	1 (50)
Gergen et al. [72]	2021	USA	Case series	Two DLT recipients with a mean age of 59 years (IQR 56–62 years) presented with COVID-19; one patient was intubated, paralyzed, and proned, and on hospital day 19, she underwent tracheostomy. The other patient required 8 L/min oxygen supplementation and was treated with remdesivir and empiric cefepime	0 (0)
Wang et al. [73]	1999	Australia	Case series	Seven patients (4 DLT, 2 SLT, 1 HLT) with a mean age of 37 ± 4.3 years were evaluated at 12 ± 8.2 months after LT to verify if the reduced oxidative capacity of peripheral skeletal muscle caused exercise limitation measuring mitochondrial oxidative phosphorylation, metabolic enzyme activity (oxidative and glycolytic), and fiber type proportion. Data were compared with seven healthy volunteers matched per age and sex	3 (43)
Munro et al. [74]	2008	Australia	RCT	36 LT recipients were allocated to two groups to compare the effects of a proactive vs. a reactive airway clearance regime using PEP therapy. In the proactive group, patients had a mean age of 45.1 ± 3.2 years, while in the reactive was 47.5 ± 3.6 years. The proactive strategy consisted of twice daily airway clearance with a PEP mask, while the reactive PEP therapy was performed only if patients had found four of six common clinical signs of chest infection (change in sputum production, increased cough, increased dyspnea, fever, radiographic changes indicative of pulmonary infection, positive sputum culture)	18 (50)

LT, lung transplant; DLT, double lung transplant; SLT, single lung transplant; IQR, interquartile range; VV-ECMO, venovenous extracorporeal membrane oxygenation; VFSE, videofluoroscopic swallowing exams; MoCA, Montreal Cognitive Assessment; POCD, postoperative cognitive dysfunction; VVLT, Visual Verbal Learning Test; SCWT, Stroop Color Word Test; CST, Concept Shifting Test; PGD, primary graft dysfunction; LT-VLA, Lung Transplant Valued Life Activities; GDS, Geriatric Depression Scale; HRQL, health-related quality of life; SF12-PCS, Short Form-12 Physical Component Score; SF12-MCS, Short Form-12 Mental Component Score; FiO_2, fraction of inspired oxygen; PaO_2, partial pressure of arterial oxygen; CLAD-BOS, chronic lung allograft dysfunction-bronchiolitis obliterans syndrome; HLT, heart-lung transplant; MV, mechanical ventilation; TwPdi, twitch transdiaphragmatic pressure; PNCT, phrenic nerve conduction time; CMAPs, compound motor action potentials; mV, millivolt; POD, postoperative day; ROM, range of motion; COVID-19, coronavirus disease 2019; CT, computed tomography; TENS, transcutaneous electrical nerve stimulation; RCT, randomized controlled trial; PEP, positive expiratory pressure.



Rehabilitative intervention

1. Enhancing activities of daily living
2. Rehabilitative surveillance, swallowing exercises
3. Electrotherapy, pain management
4. Respiratory training
5. Respiratory muscle training and aerobic exercise
6. Inspiratory muscle training
7. Acute rehabilitation
8. Secretion clearance techniques
9. Chest physiotherapy, prone positioning
10. – – –
11. Interval training
12. – – –
13. Respiratory therapy, motor rehabilitation
14. Electrotherapy
15. – – –
16. – – –
17. – – –
18. Respiratory therapy
19. Improving muscular trophism

Fig. 3. Conditions of rehabilitative interest in lung transplantation. COVID-19, coronavirus disease 2019; CLAD-BOS, chronic lung allograft dysfunction-bronchiolitis obliterans syndrome; ECMO, extracorporeal membrane oxygenation.

Table 3. Conditions of rehabilitative interest in lung transplantation

No.	Condition	Main findings
1	Graft dysfunction	· 32% of patients had grade 3 PGD (presence of new parenchymal infiltrates in the lung allograft consistent with pulmonary edema and a PaO_2/FiO_2 <200 mmHg at 72 hours after LT). Differences in functional outcomes between patients with PGD+ and PGD– were not significant: Watts (% predicted peak) 51%±19% vs. 51%±15% (p=0.89), 6-MWD 485±93 m vs. 486±99 m (p=0.96) [57]
		· 20% of patients developed grade 3 PGD. Pretransplant LT-VLA, GDS, SF12-PCS, and SF12-MCS were similar between participants with grade 3 PGD+ compared to those with PGD– (p>0.49). Improvements in LT-VLA, GDS, SF12-PCS, and SF12-MCS peaked 6 months after LT and remained relatively stable thereafter. In patients with grade 3 PGD, at 2-year follow-up, LT-VLA exceeded 2-fold the MCID, GDS exceeded 1-fold the MCID, SF12-PCS exceeded 2-fold the MCID, and SF12-MCS exceeded 1-fold the MCID [58]
2	Dysphagia	· Among the 205 patients who underwent postoperative VFSE, 20% demonstrated safe swallowing and 40% aspiration. In 170 patients who executed VFSE pre- and postoperatively, 83% demonstrated safe swallowing and 7% aspiration preoperatively; among aspirators, 50% could not eject aspirate material. Postoperatively, in the same cohort of 170 LT recipients, 16% demonstrated safe swallowing, and 45% aspiration; among aspirators, silent aspiration (accidentally inhaling something without noticing) was present in 47% [51]
		· Among 68 patients referred to speech pathology consultation, 66 underwent bedside assessment; 88% presented with oropharyngeal dysphagia. Among patients who underwent voice assessment, 62% presented with mild to severe laryngeal dysfunction, 16% were diagnosed with vocal fold palsy or paresis, and 90% of them also presented with dysphagia [52]
3	Postsurgical pain	· At the last visit, the BPI average pain score decreased from 5.6±1.8 to 4.9±2.2 points. HADS passed from 16±8.7 to 15.1±8.1 points. PCS varied from 21.3±15 to 18.3±12.5 points. SPTS varied from 33.4±11.1 to 29.4±10.3 points, and SF-MPQ-2 varied from 5.1±2.2 to 4.1±2.4 points [48]
		· 18% of participants reported persistent postsurgical pain; in 62% of them, NRS was >3 when physically active and walking. In 31% of patients, NRS was >5 when walking and 15% when physically active. 54% complained of pain during mild activities, 50% when rising from a chair or sitting down for >30 minutes or walking on stairs, and 46% while standing up for >30 minutes. In >30% of patients, pain was from more than one single body site, including the head, back, knee/hip [49]
4	Cognitive impairment	· The MoCA among LT candidates and recipients was 25±2 and 24±3, respectively. A mild impairment was present in 71% of LT candidates and 71% of LT recipients [54]
		· Postoperative neurocognitive dysfunction was present in 58% of patients (14 out of 24). The CST was significantly impaired in the number of errors (p=0.006) in the POCD group. The time needed (p=0.002) and the number of errors (p=0.016) of the SCWT were significantly higher in the POCD group [55]
		· Patients who participated in early postoperative rehabilitation had a lower risk of POCD (p<0.05) [56]
5	CLAD-BOS	· Among 116 LT recipients, 52 (45%) developed CLAD-BOS; in these patients, the NHP was higher (worse) at all follow-ups at 4,7,13,19,25,31,37,43,49 months, and differences were significant at 7,13,19,25,31 months (p<0.05, p<0.01) [60]
		· The NHP score deteriorated over 18 months posttransplant, and differences in the Energy and Mobility domains at 3 and 18 months (0 vs. 24 and 0 vs. 22 points, respectively) were significant (p<0.001). To the same extent, the STAI score deteriorated, although differences were not significant (34.08±11.34 vs. 39.79±12.73 points); the ZUNG SDS also passed from 40.89±11.73 to 49.39±12.84 points (p<0.001) and the IWB from 12.21±2.55 to 9.92±3.34 points (p=0.001) [61]

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Table 3. Continued

No.	Condition	Main findings
6	Phrenic nerve injury	· Phrenic nerve injury was detected in 43% of patients; the lesion was bilateral in 7.1%, on the right side in 23.6%, and on the left in 12.6%. The incidence was doubled in DLT vs. SLT (50% vs. 24%) [53]
		· Adjustments of pressure support ventilation from 12 cmH_2O to 8 cmH_2O were correlated with changes in EMGdi (9.8±0.71 µV vs. 17.1±1.28 µV). At 3 months, the left PNCT was 10 milliseconds, the left CMAPs were 0.970 mV, the right PNCT 11 milliseconds, and the right CMAPs were 0.837 mV. Decreased left CMAPs, prolonged left PNCT, and failure to induce right CMAPs and PNCT under bilateral magnetic stimulation were consistent with right phrenic nerve injury [63]
7	Delayed ECMO weaning	· Delayed weaning from VV-ECMO compared to immediate postoperative weaning was correlated with shorter hospital length of stay (31 vs. 46 days) and lower incidence of NIV (4.3% vs. 24.4%) and PGD (6.4% vs. 29.3%), longer ICU stay (92 vs. 88 days), longer duration of MV (44 vs. 27 hours), and higher mortality rates (10.6% vs. 7.3%) [50]
8	Airway clearance	· There was a significant improvement in FEV_1 (72%±4% to 81%±4%, $p<0.0001$) and FVC (69%±3% to 81%±3%, $p<0.0001$) with no significant differences between groups. CXR scores improved in both groups (17.8±0.5 at 1 month to 19.8±0.5 at 3 months, $p=0.002$), but no difference existed between groups. Self-reported adherence was 84% in the proactive group and 100% in the reactive. 68% of patients in the proactive group and 72% in the reactive reported no secretions at 2 months [74]
9	Refractory hypoxemia	· In 15 patients (68.2%), prone positioning was implemented within the first 72 hours after surgery and was maintained for a median of 21 hours (IQR 14.2–24 hours). PaO_2/FiO_2 increased from 81 mmHg (IQR 71.5–104 mmHg) to 220 (IQR 160–288 mmHg) ($p<0.001$). The $PaCO_2$ changed from 46 mmHg (IQR 38–54 mmHg) to 40.5 mmHg (IQR 38.2–45.5 mmHg) ($p=0.01$), and the pH from 7.36 (IQR 7.28–7.43) to 7.39 (IQR 7.34–7.47) ($p<0.001$) [59]
10	Mediastinitis	· Six deaths (28%) occurred, 33% of which were HLT and 50% DLT. *Staphylococcus aureus* contamination had a better prognosis (89% survived) than polymicrobial or fungal mediastinitis (33% survived) [62]
11	Reduced oxidative capacity	· LT recipients showed a lower peak work rate (88±10 vs. 218±30 W, $p<0.005$), VO_2 peak (18.7±1.5 vs. 36.9±2.4 mL/kg/min, $p<0.05$), HR peak (137±6 vs. 177±5 bpm), and shorter exercise duration (5.4±0.6 vs. 9±1 minutes, $p<0.05$) compared to healthy controls. LT recipients exhibited a lower proportion of type I muscle fibers (24.9%±4.4% vs. 56.1%±2.4%, $p<0.001$). In resting skeletal muscle, lactate was higher (16.3±1 vs. 8.4±0.9 mmol/L, $p<0.01$), and ATP was lower (21.4±1.2 vs. 26±1.3 RLU, $p<0.01$) in LT recipients who also exhibited lower activity of the mitochondrial enzymes ($p<0.005$) [73]
12	Sternal dehiscence	· The STRATOS device stabilized sternal dehiscence; consolidation was obtained within 2 months in all three patients [70]
13	COVID-19	· The patient was liberated from MV on POD 57 and prosecuted with physical therapy to counteract physical motor deconditioning [65]
		· One patient was weaned from a ventilator and decannulated on hospital day 38 and discharged to a rehabilitation facility. The other patient, after a first hospitalization of 6 days, was readmitted and started broad-spectrum antibiotics and high-dose steroids; the patient did not wish to be intubated and expired on hospital day 3 [72]
14	Gastroparesis	· TENS was applied with two electrodes placed in the infrascapular region and in correspondence with T5-T10 vertebrae. In one case, treatment lasted 21 hours, while in the other 19 days, both patients experienced significant improvements after the first two sessions. The electrical stimulation consisted of a 20-mA current at a rate of 150 Hz delivered in a continuous sine wave pattern for 30 minutes in both cases. At 6-month (in one case) and 1-year (in the other case) follow-up, patients were free from symptoms and stopped promobility medication [71]
15	Ossification of the elbow	· After surgical release, the ROM in the right elbow improved from –60° to 75° to –10° to 125°. The left elbow was not treated because the patient moved to another area [64]
16	Takotsubo cardiomyopathy	· The patient was extubated 6 hours after surgery, and transthoracic echocardiogram performed on POD 10 found complete recovery of left ventricle function and wall motion abnormalities. The patient was discharged home on POD 40 [66]
17	Airway dehiscence	· The procedure was well-tolerated and free from postoperative complications; at 8 weeks, complete resolution of the dehiscence was obtained, and the patient was weaned from oxygen therapy, proceeding with physical rehabilitation [74]
18	Recurrent pleural effusion	· The patient had a complicated course, and esophagrams demonstrated a continued leak. Five months after retransplantation, the patient died of respiratory failure and debility [68]
19	Scapular prolapse	· Under mild sedation, the right scapula was reduced with axial traction along the medial border while passively forward flexing the right shoulder. The patient was instructed not to move the arm for 2 weeks and immobilized and then participated in a rehabilitation program to strengthen the periscapular musculature. At follow-up, the patient had full ROM and no pain [69]

PGD, primary graft dysfunction; PaO_2, partial pressure of arterial oxygen; FiO_2, fraction of inspired oxygen; LT, lung transplant; 6-MWD, 6-minute walking distance; LT-VLA, Lung Transplant Valued Life Activities; GDS, Geriatric Depression Scale; SF12-PCS, Short Form-12 Physical Component Score; SF12-MCS, Short Form-12 Mental Component Score; MCID, minimal clinically important difference; VFSE, videofluoroscopic swallowing exams; BPI, Brief Pain Inventory; HADS, Hospital Anxiety and Depression Scale; PCS, Pain Catastrophizing Scale; SPTS, Sensitivity to Pain Traumatization Scale; SF-MPQ-2, Short McGill Pain Questionnaire-2; NRS, Numerical Rating Scale; MoCA, Montreal Cognitive Assessment; CST, Concept Shifting Test; POCD, postoperative cognitive dysfunction; SCWT, Stroop Color Word Test; CLAD-BOS, chronic lung allograft dysfunction-bronchiolitis obliterans syndrome; NHP, Nottingham Health Profile; STAI, State Trait Anxiety Inventory; SDS, Self-rating Depression Scale; IWB, Index of Well-Being; DLT, double lung transplant; SLT, single lung transplant; EMGdi, diaphragm electromyogram; PNCT, phrenic nerve conduction time; CMAPs, compound motor action potentials; ECMO, extracorporeal membrane oxygenation; VV-ECMO, venovenous ECMO; NIV, noninvasive ventilation; ICU, intensive care unit; MV, mechanical ventilation; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; CXR, chest X-ray; IQR, interquartile range; $PaCO_2$, partial pressure of carbon dioxide; HLT, heart-lung transplant; W, Watts; VO_2, peak oxygen consumption; HR, heart rate; bpm, beats per minute; ATP, adenosine triphosphate; RLU, relative light units; STRATOS, Strasbourg Thoracic Osteosyntheses System; COVID-19, coronavirus disease 2019; POD, postoperative day; TENS, transcutaneous electrical nerve stimulation; ROM, range of motion.

diffuse allograft infiltration/pulmonary edema [81]. The incidence of PGD is estimated to be approximately 30%, with 10% to 20% of patients developing PGD grade 3 [81], which aligns with the findings of the present review (Table 3). Although PGD is a leading cause of early morbidity and mortality, functional outcomes overlap in LT recipients with or without PGD [57]. In addition, it seems that PGD at 2 years in LT recipients is not associated with poorer health-related quality of life or physical disability [58]. Therefore, postoperative rehabilitation in such a class of patients should be provided, as PGD can lead to an extended period of illness and ICU stay. The aim is to maximize outcomes and enhance activities of daily living in the context of quasi-preserved motor and respiratory autonomy, at least during the initial postoperative timeframe, increasing the possibilities of successfully overcoming an eventual retransplantation [82-84].

2. Dysphagia

In the present review, aspiration and laryngeal dysfunction were observed in a significant percentage of LT recipients (45% and 62%, respectively) (Table 3). These findings are consistent with the need to investigate deglutition posttransplant and implement rehabilitative surveillance by early referral to speech therapists in postoperative settings. Furthermore, fiberoptic endoscopic evaluation of swallowing or videofluoroscopic swallowing examinations should be performed to identify patients who are at risk of dysphagia-related respiratory complications [85].

3. Postsurgical pain

Pain is a significant concern in patients receiving LT as it can hinder activities of daily living, such as walking or sitting, and lead to postoperative pulmonary complications owing to the inability to breathe deeply. Pain may be persistent posttransplant, as found in the present review (Table 3), and its intensity on the numerical rating scale may be higher than five out of 10 in LT recipients [86], which is considered to be pain of substantial intensity [87]. Optimizing opioid management in the postoperative period is a collaborative effort that involves consulting physiotherapists and nurses who specialize in postsurgical pain management. This multidisciplinary approach is crucial for guiding patients toward a functional recovery [48,49]. Physiotherapeutic methodologies play a pivotal role in this context. These methodologies help reduce reliance on opioids and alleviate pain, empowering healthcare professionals in their role. Transcutaneous electrical nerve stimulation (TENS) is an excellent example of these methodologies [88,89].

4. Cognitive impairment

Rehabilitation requires patients to cooperate to maximize therapeutic effects. Passive techniques are also a viable option in cases that are not amenable to active treatment, although they have limited benefits in restoring active functional ability. In the context of LT, the rehabilitative postoperative course is particularly important because motor and respiratory training significantly contributes to restoring function [30,36,90,91]. A certain degree of cognitive deterioration is compatible with effective rehabilitation, being aware that more than 50% of LT recipients could be affected by mild cognitive impairment and that patients participating in early postoperative rehabilitation are at lower risk of developing cognitive dysfunction (Table 3).

5. Chronic lung allograft dysfunction-bronchiolitis obliterans syndrome

Chronic lung allograft dysfunction-bronchiolitis obliterans syndrome (CLAD-BOS) is a progressive airflow obstruction unexplained by acute rejection, infection, or other confounding complications and is characterized by submucosal fibrosis involving the respiratory bronchioles, resulting in occlusion of the airway lumina [92,93]. CLAD-BOS is defined as a substantial and persistent decline ($\geq$ 20%) in measured forced expiratory volume in 1 second (FEV_1) from the reference (baseline) value (baseline = mean of the best two postoperative FEV_1 measurements taken > 3 weeks apart) [94]. The incidence of CLAD-BOS is approximately 50%, and it is associated with poor survival [60,92]. Among the critical risk factors for the development of CLAD is acute graft rejection, as an increase in the severity and number of episodes of acute rejection is associated with an increased risk of CLAD-BOS [95,96]. The incidence of acute rejection is estimated to range from 17% to 49% in the first year after transplantation, with a higher risk in the first few months after surgery. Acute rejection may be asymptomatic or present with nonspecific symptoms, such as dyspnea, cough, mucus production, and low-grade fever [94]. Therefore, particularly in the first postoperative period, it is important to monitor symptoms that could be evoked by motor activities and to monitor the patient's rehabilitation progression. As expected, among the LT recipients with CLAD-BOS included in the present review, subjective health status, anxiety and depression, and well-being worsened over time compared to that of patients without CLAD-BOS (Table 3). It has been found that rehabilitation consisting of respiratory muscle strength training and aerobic exercise is a viable option in patients with CLAD-BOS and is effective at improving exercise capacity, dyspnea, lung function, and peak oxygen uptake consumption [97], warranting further investigations.

6. Phrenic nerve injury

The phrenic nerve maintains diaphragmatic function. It can be subjected to surgery-related injuries or suffer intraoperative maneuvers, resulting in diaphragmatic weakness [98]. In the present review, the incidence of phrenic nerve injury was 43%, with the right hemidiaphragm much more affected than the left (Table 3) in accordance with other data from LT cohorts [99]. It has been suggested that patients with diaphragmatic weakness should undergo rehabilitative treatment. The treatment primarily focuses on restoring the strength and function of the diaphragm and is particularly beneficial for patients who are asymptomatic as they are more likely to recover fully [100]. Inspiratory muscle training can be used to overcome diaphragmatic weakness and is a viable treatment option, particularly in cases of prolonged mechanical ventilation due to diaphragmatic weakness [101].

7. Delayed extracorporeal membrane oxygenation weaning

ECMO is increasingly used as a bridge to LT and immediately after surgery to optimize postoperative organ recovery [102,103]. In a comparative study, delayed ECMO weaning after surgery correlated with a shorter hospital length of stay (LOS) (due to a lower incidence of atrial fibrillation), and lower incidence of noninvasive ventilation and PGD [50], longer ICU LOS, and prolonged mechanical ventilation have been reported (Table 3). Therefore, it can be assumed that patients who experience delayed weaning from ECMO may require more intense rehabilitation in the ICU, as rehabilitation plays a crucial role in reducing ICU and hospital LOS and increasing the odds of a shorter time on mechanical ventilation [104]. At the same time, the feasibility of rehabilitation and related advantages for patients on ECMO have been confirmed [105,106], even in patients with coronavirus disease 2019 (COVID-19) [107], and rehabilitation is increasingly accepted as a standard of care in ECMO settings [108]. Therefore, awake ECMO plays a role in the management of LT recipients.

8. Airway clearance

Secretion clearance is facilitated by the normal function of airway cilia; in LT recipients, clearance is impaired for several weeks postoperatively [109]. This is worsened by impaired cough, which is typically present in LT recipients and leads to the accumulation of bronchial secretions. In the present review, it was found that there was no significant difference between patients who regularly underwent airway clearance and those who adopted a proactive strategy (Table 3) where specific clearance exercises were performed only when a chest infection was indicated [74]. Such an approach should be considered during the postoperative course and adapted to the patient's specific condition while being aware of the importance of avoiding mucus retention and, contextually, providing the most personalized and effective treatment for the patient.

9. Refractory hypoxemia

Postoperative hypoxemia may be induced by PGD in more than 50% of LT recipients [110] and may be of importance to rehabilitation professionals. Prone positioning under mechanical ventilation is used to improve gas exchange in cases refractory to a >60% increase in the FiO_2 [111], although there are possible complications such as pressure ulcers, nerve lesions, surgical wound dehiscence, accidental extubation, and endotracheal tube obstruction or decannulation [112,113], which may further delay the postoperative course. The patients in this review who were treated with prone positioning to counteract refractory hypoxemia within 72 hours postoperatively experienced significantly improved PaO_2/FiO_2 and partial pressure of carbon dioxide (Table 3). Prone positioning should be conducted in a multidisciplinary context by teams of at least six professionals from different fields, including physicians, physiotherapists, nurses, and technicians. These teams should use a safe-prone checklist to avoid the potential onset of complications [113]. Among other rehabilitative interventions, chest physiotherapy techniques to increase lung volume can effectively address hypoxia caused by atelectasis [114].

10. Mediastinitis

Postoperative mediastinitis-related complications can pose risks including death (Table 3) and should be diagnosed early and managed with debridement and irrigation via resternotomy to avoid tissue destruction [62]. In the rehabilitative context of LT, when patients are subjected to reoperation, this often represents an additional challenge overlapping with the underlying clinical situation because patients are exposed to a series of negative factors such as surgical site-related complications, mood deterioration, and mobility restriction. As mediastinitis can be caused by polymicrobial or fungal infections [62], specific attention to infection control measures is paramount, considering that rehabilitation professionals could be a source of cross-infection as they travel from patient to patient, contributing to the spread of microorganisms.

11. Reduced oxidative capacity

Oxidative capacity (μL O_2/hr/g) measures the muscle's maximal capacity to use oxygen [115]. In the present review, LT recipients exhibited a lower peak work rate, peak oxygen consumption, and a lower proportion of type I muscle fibers (slow-oxidative) (Table 3), which are rich in mitochondria and myoglobin (sustained contraction with low tension). Therefore, muscle exercise should include training at low intensity with a high number of repetitions at > 70% of the one-repetition maximum and should elicit greater aerobic activity, as occurs during interval training [116,117].

12. Sternal dehiscence

Postoperative sternal dehiscence (after LT via clamshell incision) complicates the recovery pathway and delays rehabilitation [70]. The etiology of sternal dehiscence is multifactorial and includes several conditions such as osteopenia, malnutrition, and severe cases requiring surgical treatment [70,118]. Using a specific titanium implant system has been suggested to enhance postoperative recovery, reduce the sternal gap, and favor consolidation (Table 3). Solid immobilization with dynamic compression is performed without direct osteosynthesis onto the fragile and osteoporotic bones. The system is removed when consolidation is achieved or retained for a longer time if needed [70]. Nevertheless, its use is not free from complications such as rib fractures or fractures/loosening of the system components; these events have been reported in patients with pectus deformities [119,120]. Therefore, rehabilitation should be provided to patients with wound dehiscence. However, this may be limited by pain, and the use of the upper limbs may be restricted to prevent further wound issues. At the same time, it should not be forgotten that airway complications such as anastomotic dehiscence, bronchial stenosis, and bronchomalacia (> 50% decrease in the luminal diameter on exhalation) are much more common than sternal dehiscence, accounting for a 2% to 4% mortality after LT with an incidence ranging from 2% to 33%. However, these conditions are typically not responsive to rehabilitation and are managed surgically [42].

13. Coronavirus disease 2019

Patients receiving solid organ transplantation are at a higher risk of severe COVID-19 disease because of the underlying comorbid conditions and immunosuppression [72,121]. It has been estimated that the incidence of COVID-19 in LT recipients does not substantially differ from that of the general population, and symptoms can range from severe (acute respiratory distress syndrome) to mild (cough, fever, sore throat, headache, arthromyalgia, anosmia, nausea, or asthenia) [122-126]. Indeed, COVID-19 graft pneumonia may result in respiratory failure with imaging revealing lung infiltrates, ground-glass opacities, and consolidation requiring respiratory support [122,123]. The primary goals in the presence of respiratory failure are to (1) address oxygen requirements, (2) maintain a low level of breathing work, and (3) reserve intubation for individuals exhibiting refractory hypoxemia [126]. Rehabilitation of patients with COVID-19 has been demonstrated to be effective in managing motor- and respiratory-related complications, even in critical and subintensive settings [107,127]. In the present review, LT recipients were discharged to a rehabilitative setting after the acute phase of infection, although one patient died (Table 3). While rehabilitative techniques used in LT recipients with COVID-19 [128] do not substantially differ from those without COVID-19, rehabilitation of the former is complicated by the typical respiratory symptoms of COVID-19 that could overlap with underlying dyspnea and the deteriorated motor capacity due to forced bed rest [129].

14. Gastroparesis

Professionals involved in the postoperative rehabilitation of LT recipients should be aware that gastroparesis can be treated with instruments typically used in daily practice, such as TENS devices [71]. The TENS electrodes should be applied to the infrascapular region in correspondence with the thoracic spine (Table 3). Since gastroparesis can be associated with back pain [71], a differential rehabilitative diagnosis should be considered in this class of patients. However, the use of TENS for the treatment of gastroparesis is rare in the clinical rehabilitative scenario, and further investigation is needed to obtain more robust evidence and understand whether this technique could become a consolidated rehabilitative practice.

15. Ossification of the elbow

In the present review, it was found that four patients, one of whom was an LT recipient, developed heterotopic ossification at the elbow [64], which is a rare and unique condition in the transplantation setting (Table 3). It should be noted that all four patients had encephalopathy, and the authors noted that they might have been restrained to the bed using wrist cuffs to immobilize their arms to avoid self-induced injuries. Therefore, the underlying mechanism responsible for the development of heterotopic ossification could be improper fastening and compression of the elbow. With the improved management of patients in critical settings, such conditions should be avoidable.

16. Takotsubo cardiomyopathy

Takotsubo cardiomyopathy is an acute reversible heart failure syndrome that is stress-induced and characterized by abnormal left ventricular wall motion abnormalities [130,131]. It is rare among LT recipients, as its incidence ranges from 0.3% to 1.7% in liver transplants, with fewer cases in kidney, heart, and lung transplants. Spontaneous regression is expected in 3 weeks, and in-hospital mortality is 4% [130]. The treatment of Takotsubo cardiomyopathy does not include rehabilitation (Table 3), although the results of possible intubation or a forced period of rest are physiotherapeutically pertinent.

17. Airway dehiscence

Bronchial dehiscence is a potential postoperative airway complication of LT, together with tracheobronchomalacia, bronchial fistulas, and endobronchial infections, among others. Infections and sirolimus-based immunosuppression can cause dehiscence resulting from ischemia that tends to occur within 3 months after surgery [132]. Symptoms of dehiscence include dyspnea, pneumomediastinum, subcutaneous emphysema, lung collapse, persistent air leak, and a drop in FEV_1 [132]. Dehiscence cannot be treated with rehabilitation (Table 3), but its symptoms should be considered carefully by rehabilitation professionals, particularly if they appear < 3 months after LT. For example, rehabilitation professionals should be aware of the difference between postoperative and dehiscence-related dyspnea. Indeed, in the former case, exercise could contribute to reconditioning and reduce dyspnea perception, whereas in the latter case, it could be contraindicated.

18. Recurrent pleural effusion

Pleural effusion is an excessive accumulation of fluid in the pleural space and can be caused by different conditions such as pulmonary embolism, viral diseases, rheumatoid disease, gastrointestinal disease, tuberculosis, and thoracic surgical procedures [133-135]. Possible pleural effusion symptoms include chest pain, dyspnea, and dry cough (which mainly depend on the amount of fluid) and should be drained when causing severe respiratory symptoms [133]. Rehabilitative techniques can be used in a multidisciplinary context to treat pleural effusion after cardiac surgery and solid organ transplantation [136,137]; therefore, such techniques should be considered for treating postoperative pleural effusion in LT recipients. However, in the present review, only one patient suffered from pleural effusion caused by esophageal perforation, resulting in death. When managing pleural effusion in LT recipients, the underlying cause should be carefully evaluated to understand whether pleural effusion is amenable to rehabilitative techniques (Table 3).

19. Scapular prolapse

Scapular prolapse has been described in the literature as a consequence of thoracic surgical procedures, although it is a rare event that can occur between 1 month and 1 year after surgery. It presents with pain and range of motion limitations in the shoulder, whose solution is mainly manual reduction with symptom resolution (Table 3) [69,138-141]. The underlying mechanism should be better defined, although weakness of the chest wall and muscle deconditioning may play significant roles. We speculate that a rehabilitative approach aimed at improving muscle tropism of the upper girdle postoperatively as well as kinematic evaluation of glenohumeral joint-related structures should be considered.

Further considerations

A physiotherapist's performance when approaching patients receiving LT depends on various key aspects of the work environment, including the volume of procedures performed, patient selection, and the ability to work in a team [142]. Postoperative rehabilitation after LT begins in the ICU and continues in an outpatient setting for as long as needed, with rehabilitative protocols generally lasting several weeks. Four key domains should be considered for LT candidates. Specifically, nutritional depletion, inactivity and motor deconditioning, lower limb muscle dysfunction, and oxygen dependency, complicate rehabilitative interventions [142]. Therefore, rehabilitation should be proposed as early as possible with the patient on the waiting list (prehabilitation) to optimize preoperative function and strength. Once LT is performed, patients should be involved in postoperative activities to enhance their respiratory and motor functions, and long-term rehabilitative protocols are crucial for maximizing surgical outcomes [142]. Therefore, rehabilitation of patients undergoing LT can be divided into different phases characterized by specific goals and practices (Fig. 4). In contrast, rehospitalizations are common after LT, ranging between 30% and 92%, depending on the time point [143]. However, patients involved in postoperative rehabilitation and discharged to an inpatient rehabilitation facility are less likely to be readmitted to a hospital within the first 30 days, highlighting the importance of implementing stable and long-lasting rehabilitative programs in LT centers [143].

Limitations

The present study has limitations. First, it was not possible to extract all demographic information from the included studies. Therefore, the material provided here could be difficult to extrapolate to a specific patient's sex or age. Second, the use of different keywords would have returned different results, although we are confident that the search strategy was appropriate to address the purpose of the study, as all the conditions we have identified can impact the postoperative rehabilitative course. Finally, there were numerous conditions, including some very rare (e.g., Takotsubo cardiomyopathy, gastroparesis, elbow ossification, and scapular prolapse), which prevented the generalization of the information presented here to a wider context. However, despite their rarity, some of the outlined conditions can lead to delayed recovery.

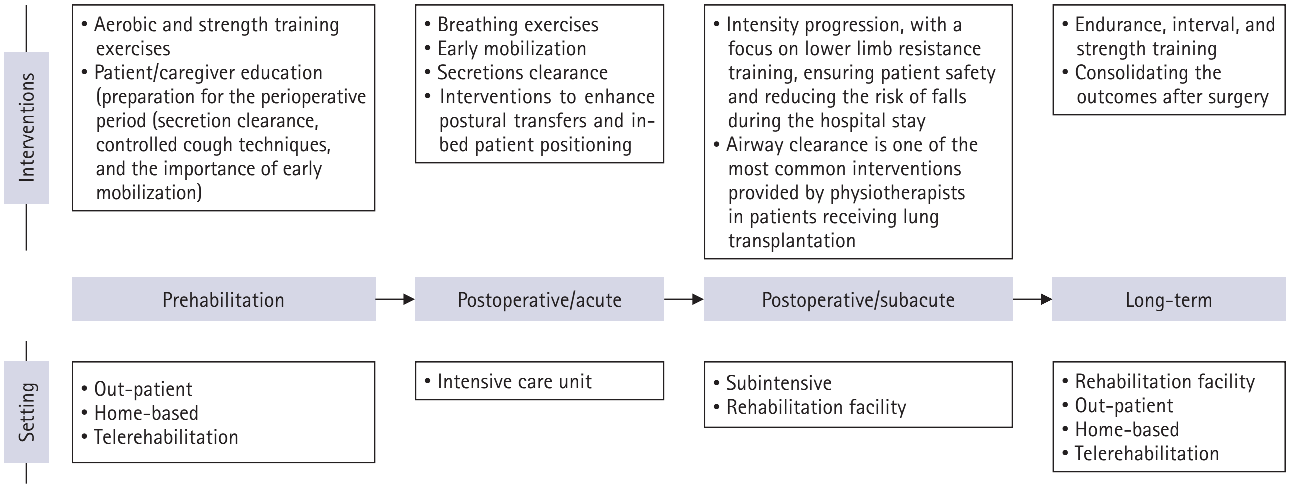

Fig. 4. Rehabilitative phases and settings.

Awareness of their possible occurrences can be beneficial for the postoperative pathway.

Conclusion

Postoperative rehabilitation after LT may be characterized by the onset of clinical conditions that can delay recovery, and professionals involved in the rehabilitation of patients undergoing LT should be aware of the negative effects on motor and respiratory functions. The present review highlighted 19 conditions that may complicate the postoperative recovery of LT recipients. While some conditions are not amenable to rehabilitative techniques, others can significantly improve with rehabilitation, as we found in the literature. Early detection and treatment of these clinical conditions, which can potentially complicate rehabilitation, are recommended to minimize their impact on patient outcomes.

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