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Original Research

Multidisciplinary Inpatient Rehabilitation Following Heart and/or Lung Transplantation—Examining Cohort Characteristics and Clinical Outcomes

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Abstract

Background: Cardiopulmonary transplantation is becoming a more common treatment option for advanced heart and/or lung disease. Specialist rehabilitation programs may assist recovery and enhance functional independence following transplantation.
Objective: To quantify the outcomes of multidisciplinary inpatient rehabilitation following cardiopulmonary transplantation and describe cohort characteristics.
Design: Retrospective cohort study.
Setting: Subacute inpatient rehabilitation facility, located on-site at Australia's largest cardiopulmonary transplant center.
Participants: Heart and/or lung transplant recipients (n = 116), admitted for multidisciplinary inpatient rehabilitation, between 2009 and 2016.
Interventions: All participants received multidisciplinary rehabilitation as part of their standard care.
Main Outcome Measurements: Participants' functional independence was scored using the Functional Independence Measure (FIM) upon rehabilitation admission and discharge. Physical measures of mobility and balance were assessed at the same time points, including the 6-minute walk test, 10 m walk, Timed Up and Go, and Berg Balance Scale. Process measures of interest included rehabilitation length of stay, interruptions to rehabilitation, and discharge destination.
Results: Average length-of-stay in rehabilitation was 26.9 $\pm$ 21.2 days (mean $\pm$ SD). FIM scores improved from 79.8 $\pm$ 20.3 on admission to 101.8 $\pm$ 29.1 at discharge ($P < .001$) for the pooled cohort. Physical measures of mobility and balance also improved: 6-minute walk test distances improved from 103.6 $\pm$ 80.1 to 183.2 $\pm$ 104.8 m ($P < .001$); Timed Up and Go results decreased from 26.4 $\pm$ 18.3 seconds to 16.5 $\pm$ 14.1 seconds ($P < .001$); and Berg Balance Scale scores increased from 26.8 $\pm$ 17.1 to 45.0 $\pm$ 9.4 ($P < .001$). Approximately one-third (33.6%) of admissions were interrupted by an acute medical complication; however, this did not preclude completion of rehabilitation or achievement of functional gains. Ninety-four percent of the cohort was discharged to a private residence following rehabilitation. No significant differences were observed between heart versus lung transplant recipients.
Conclusions: For debilitated patients following heart and/or lung transplantation, physical function, mobility, and independence significantly improved following multidisciplinary inpatient rehabilitation.
Level of Evidence: III

Introduction

Solid organ transplantation of the heart and/or lungs is increasingly being used as a treatment option for end-stage cardiopulmonary disease. Continued improvements in organ salvage and medical and surgical techniques have resulted in greater numbers of transplant operations being performed each year, with over 5000 heart transplants and 4000 lung transplants recorded by the International Society for Heart and Lung Transplantation globally in 2015.[1,2] Improvements in the medical management of posttransplant

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complications and organ rejection have also increased transplant survival, to a median of 10.7 years following heart transplant[1] and 6.0 years following lung transplant.[2]

Patients who receive transplants for end-stage disease are typically deconditioned from preoperative cardiac or respiratory failure, and are often physiologically frail.[3] This is compounded by the effects of major surgery and prolonged hospitalization, which may result in further weakness, myopathy, neuropathy, and other immobility-associated complications.[4,5] Together with antirejection medication regimens, immunosuppression, metabolic disturbances, nutritional depletion, and at times concomitant mood disorders, these various factors all contribute to activity limitations that can impair function and quality-of-life for years after transplantation.[6–10]

Although transplant recipients represent a unique patient population, these sequelae are common to many critically ill and deconditioned patients treated in a rehabilitation setting. Given the medical complexity of transplant patients, the high risk of complications and the need for close monitoring, the inpatient rehabilitation setting has been suggested as ideal for this population, particularly those with a complicated medical and/or surgical course.[11]

There is growing interest in the role of rehabilitation for patients following heart and/or lung transplantation, but the available literature remains limited. Most research to date has focused on outpatient rehabilitation models delivered after patients have been stabilized and discharged from hospital, with support for pulmonary rehabilitation[4,12] and exercise-based cardiac rehabilitation interventions.[13,14] Little has been done investigating multidisciplinary inpatient rehabilitation in the acute phase following transplantation surgery. The earliest data come from Bowman and colleagues, who report functional improvements following rehabilitation among a cohort of 86 heart and/or lung transplant recipients between 2002 and 2009.[15] Patcai et al also report seminal data but from a mixed cohort of solid organ transplant recipients receiving inpatient rehabilitation, including 56 heart/lung transplant patients. They observed functional gains postrehabilitation, but improvements were more modest, required longer lengths of stay, and were associated with higher complication rates among transplant patients compared to general rehabilitation patients.[16] Later work by Gupta et al in a small cohort of exclusively heart transplant recipients supported earlier findings that inpatient rehabilitation can lead to functional benefits after transplantation.[17]

The present study aimed to extend on the work of Bowman et al by conducting an updated review of inpatient rehabilitation outcomes following cardiopulmonary transplantation, at the largest Heart and Lung Transplant center in Australia and New Zealand, from 2009 to 2016.

Methods

Setting

St Vincent's Hospital Sydney has the oldest and largest heart and lung transplant unit in Australia.[18] Rehabilitation services at St Vincent's Hospital are provided by the Sacred Heart Rehabilitation Unit, which houses an onsite, 32-bed specialist inpatient rehabilitation unit.

Following transplantation surgery, patients in an acute care unit are assessed by the rehabilitation team at the request of the treating transplant team. Typically this occurs when a patient is medically and surgically stable, but experiences ongoing mobility limitations, severe deconditioning, requires high levels of personal care assistance, or has experienced other complications, such as critical illness neuropathy. If deemed suitable, patients are transferred to the rehabilitation ward where they are managed by a multidisciplinary rehabilitation team, with regular and ongoing liaison with the transplant team.

Inpatient Rehabilitation Program

The rehabilitation team comprises medical, nursing, physiotherapy, occupational therapy, dietetics, speech therapy, social work, and psychology disciplines. Together, the team designs an individualized program for each patient, taking into account their needs, level of deconditioning, and comorbidities. Core components of transplant rehabilitation programs include cardiopulmonary reconditioning, muscle strengthening, functional retraining, nutritional review, education regarding drug management, psychological support, and adjustment counseling.

In the subacute inpatient setting, physical therapy is central to the rehabilitation program. Patients receive a minimum of 60 minutes of one-to-one physiotherapy per day, completed over one or multiple sessions if required to manage fatigue, and supplemented by additional group therapy when patients are sufficiently mobile. Strengthening exercises with a strong focus on functional movements (such as sit-to-stand) are used to address global deconditioning, often with a particular focus on weakness of the gluteal and hip extensor muscles caused by prolonged bed rest and time spent in supported seated positions. Dynamic strength training of the upper and lower limbs is performed via largely body-weight resisted exercises, with gradual progression to increased repetitions and the use of free weights as the patient is able. Cardiovascular fitness is targeted via walking (treadmill or regular), cycling, and the use of MOTOmed-assisted exercise equipment (RECK-Technik GmbH & Co. KG, Germany) for those with severe weakness or mobility impairments. Exercise intensity is monitored via the Borg Rating of Perceived Exertion scale,[19] with patients encouraged to achieve a target of "somewhat hard"

activity (scores 12-14). Balance training and targeted practice of activities of daily living are other key components of inpatient programs. For cardiopulmonary transplant recipients, physical therapy also has a strong focus on breathing retraining, and the provision of education and supported psychological strategies to better understand breathlessness and overcome fears of exercise and dyspnea on exertion.

Study Design

A retrospective audit was conducted, reviewing all admissions to inpatient rehabilitation at the Sacred Heart Rehabilitation Unit, St Vincent's Hospital Sydney, between January 2009 and December 2016. All admissions with a primary diagnosis of heart and/or lung transplant were included in the analyses. Review of the patient's medical record was used to extract the following outcomes for each admission: demographic variables including age, sex, diagnosis, and type of transplant; length of stay; interruptions to rehabilitation; Functional Independence Measure (FIM) score on admission and discharge; and discharge destination. All patients were assessed by physiotherapists on admission to inpatient rehabilitation and before discharge. Where possible, the following physiotherapy outcome measures were collected: 6-minute walk test (6MWT), 10-m walk, Timed Up and Go (TUG), and the Berg Balance Scale.

To enable basic cohort comparisons between transplant recipients who did and did not require inpatient rehabilitation, acute hospital admission records were reviewed to identify *all* patients admitted for heart or lung transplantation surgery between 2009 and 2016. Data on age, type of transplant, acute hospital length of stay, intensive care unit (ICU) length of stay, duration of mechanical ventilation, and deaths during admission were collected.

This study was approved by the human research ethics committee of St Vincent's Hospital Sydney (LNR/15/SVH/367) and conducted in accordance with the Declaration of Helsinki.

Data Analyses

For parametric data, paired *t*-tests were used to examine changes in FIM score and physiotherapy assessment measures over time (rehabilitation admission to discharge), whereas independent-sample *t*-tests were used to compare outcomes between patient subgroups who underwent heart versus lung transplantation. Nonparametric variables were analyzed via Wilcoxon signed-rank tests or Man-Whitney *U* tests, whereas categorical variables were analyzed via chi-square analyses. Demographic comparisons between transplant recipients who did and did not receive inpatient rehabilitation were performed using Mann-Whitney *U* tests (for continuous variables), and Fisher' exact test (for deaths during admission). All statistical analyses were conducted in SPSS v23 (IBM, Armonk, NY), and differences were considered significant where $P < .05$.

Results

All Heart and/or Lung Transplants

During the audit period (2009-2016), St Vincent's Hospital Sydney performed a total of 225 heart transplantations, 369 lung transplantations, and 9 combined heart and lung transplantations. Over the same period, a total of 116 admissions were made to inpatient rehabilitation following transplantation, representing 19.2% of all acute admissions for transplantation surgery. This included 49 orthotopic heart transplantations, 65 lung transplantations (59 double-lung and 6 single lung), and 2 combined heart-lung transplantations.

There were a number of demographic differences between transplant recipients who did and did not require inpatient rehabilitation, as outlined in Table 1. Lung transplant recipients who required rehabilitation were significantly older than those who did not ($P < .001$), whereas age did not differ among heart transplant cohorts. For both heart and lung transplant recipients, the median length of stay in ICU and in the acute hospital was significantly longer for patients

Table 1
Demographic comparisons of transplant recipients who did and did not require inpatient rehabilitation

	Heart transplant recipients 2009-2016			Lung transplant recipients 2009-2016		
	Inpatient rehabilitation	NO inpatient rehabilitation	*P* value	Inpatient rehabilitation	NO inpatient rehabilitation	*P* value
Count	n = 49	n = 176		n = 65	n = 304	
Age (mean ± SD)	51.7 ± 13.3	49.4 ± 13.2	.197	55.0 ± 11.2	45.9 ± 15.1	**<.001***
ICU length of stay (d)	17 [12-27]	5 [3-9]	**<.001***	16 [7-34]	5 [3-8]	**<.001***
Acute hospital length of stay (d)	57 [39-71]	20 [14-30]	**<.001***	45 [27-66]	16 [12-25]	**<.001***
Time on mechanical ventilation (h)	129 [62-259]	27 [16-97]	**<.001***	116 [34-254]	21 [13-47]	**<.001***
Deaths during admission, n (%)	3 (6.1%)	14 (8.0%)	.174	2 (3.1%)	18 (5.9%)	.332

Age is presented as mean ± SD; other data are presented as median [interquartile range]. *P* values indicate differences between cohorts who did and did not receive inpatient rehabilitation, for heart or lung transplantation, respectively.
*Indicates statistical significance.

Table 2
Rehabilitation cohort demographics

	Heart	Lung	Combined heart-lung
Count	n = 49	n = 65	n = 2
Age			36 and 49
mean [range]	51.7 [21-69]	55.0 [23-71]	
Sex			
Male	25 (51%)	37 (57%)	1 (50%)
Female	24 (49%)	28 (43%)	1 (50%)
Previous transplant?	3 (6%)	4 (6%)	0
Reasons for transplant	Idiopathic dilated cardiomyopathy 21 Ischemic cardiomyopathy 12 Viral cardiomyopathy/ myocarditis 9 Familial cardiomyopathy 5 Congenital heart defects 2	Interstitial lung disease i) idiopathic pulmonary fibrosis 26 ii) sarcoidosis 1 iii) scleroderma 1 iv) hypersensitivity pneumonitis 1 v) polymyositis 1 Cystic fibrosis 4 Non-CF bronchiectasis 6 Emphysema 17 Emphysema secondary to alpha-1 antitrypsin deficiency 5 Obliterating bronchiolitis 1 Wegener's granulomatosis 1 Pulmonary hypertension 1	Dilated cardiomyopathy and pulmonary hypertension 2
Premorbid use of cardiac assistive device	BiVAD 1 LVAD 14 AICD 20 PPM 5	N/A	AICD 1
Days postsurgery at commencement of rehabilitation	51.7 ± 24.0	47.6 ± 34.1	33 and 50
Admission FIM (score/126)	80.4 ± 19.2	79.7 ± 21.4	61 and 78
Rehabilitation length of stay (days)	26.4 ± 22.8	26.5 ± 20.5	22 and 24
Interruption to rehabilitation?	13 (26.5%)	25 (38.5%)	1 (50%)
Discharge destination	Private residence 45 Regional hospital 1 Died in hospital 3	Private residence 62 Regional hospital 1 Died in hospital 2	Private residence 2

Data are presented as mean [range]; number (%); or mean ± SD. BiVAD = biventricular assistive device; LVAD = left ventricular assistive device; AICD = automatic implantable cardioverter-defibrillator; PPM = permanent pacemaker; FIM = Functional Independence Measure.

subsequently needing rehabilitation; in both cases, more than double the duration of nonrehabilitation patients (see Table 1). The amount of time spent on postoperative mechanical ventilation was also significantly longer for rehabilitation versus nonrehabilitation patients ($P < .001$). The proportion of transplant recipients who died during admission did not differ according to rehabilitation status, following either heart or lung transplantation.

Transplant Recipients Who Received Inpatient Rehabilitation

The pooled rehabilitation cohort comprised 63 men and 53 women, with a mean age of 53.4 ± 12.2 years (mean ± SD). Full demographic details for the rehabilitation cohort according to transplant type are presented in Table 2. Mean length of stay in rehabilitation was 26.9 ± 21.2 days, whereby rehabilitation admissions immediately followed from acute hospital admissions, as outlined in Table 1. Interruptions to rehabilitation due to medical complications occurred in 39 admissions (33.6%). These all resulted in return to an acute care ward, and reasons included: infection (8); pleural effusion (8); acute respiratory distress (6); sepsis (5); acute renal failure (3); rapid atrial fibrillation (2); rejection (3); pulmonary embolus (1); stroke (1); hypotension (1); and pancreatitis (1). All documented complications were related to patients' underlying disease states. No serious complications were reported as a direct result of participating in rehabilitation activities, such as falls, injuries, or adverse events during therapy. Among those patients with a rehabilitation interruption, 24 were able to return to rehabilitation and complete their program after being medically stabilized, 9 were discharged from the acute hospital, and 5 died in acute care.

Table 3
Improvements on the Functional Independence Measure (FIM) with rehabilitation

	All rehabilitation patients (n = 116)			Patients without a rehabilitation interruption (n = 77)	
	Heart	Lung	Combined heart-lung	Heart	Lung
Count	n = 49	n = 65	n = 2	n = 36	n = 40
Admission FIM total	80.4 ± 19.2	79.7 ± 21.4	78; 61	85.3 ± 16.9	85.4 ± 17.1
Discharge FIM total	103.7 ± 29.2	99.9 ± 29.5	121; 115	114.4 ± 13.5	110.4 ± 16.4
FIM gain total	23.3 ± 21.6	20.2 ± 26.9	43; 54	29.1 ± 13.8	25.1 ± 14.2
FIM efficiency (total gain/ length-of-stay)	1.0 ± 1.1	.8 ± 1.6	1.8; 2.5	1.3 ± .7	1.3 ± .8
P value	<.001*	<.001*	N/A (only n = 2)	<.001*	<.001*

Data are presented as mean ± SD, except for combined heart-lung transplantations, where n = 2 and individual patient data are provided. *P* value corresponds to change over time from admission to discharge.
*Indicates statistical significance.

Overall, the mean FIM score on admission to rehabilitation was 79.8 ± 20.3, and this significantly improved to 101.8 ± 29.1 on discharge ($P < .001$). This resulted in a mean FIM efficiency of .9 ± 1.2, representing a positive change of approximately 1 point on the FIM per day of admission. For those rehabilitation admissions that did not experience an interruption, mean admission FIM was 85.2 ± 16.9, mean discharge FIM was 112.4 ± 15.1, and FIM efficiency was 1.3 ± 0.8 (see Table 3). Average FIM improvements by transplant type (heart, lung) are outlined separately in Table 3.

Of the 116 patients admitted to rehabilitation, 109 were discharged home or to private accommodation, 2 were transferred to a regional hospital, and 5 died in hospital.

Physiotherapy Outcomes

Physiotherapy assessment data were available for 80 patients (70% of the rehabilitation cohort). At admission, severe debility and/or inability to mobilize resulted in 22 patients being unable to perform the 6MWT (27.5%), 19 patients were unable to perform the 10-m walk test (23.8%), and 26 patients were unable to perform the TUG (32.5%). In 14 cases (17.5%), complications resulting in a sudden transfer to the acute hospital and/or an earlier than expected discharge prevented the completion of discharge assessments.

For those patients for whom admission and discharge physiotherapy data were available, significant improvements were seen across all measures (see Table 4).

Comparing Rehabilitation of Heart and Lung Transplants

When comparing patients who received heart versus lung transplants, no significant between-group differences were found for any variables, including age ($P = .14$), length of stay ($P = .92$), admission FIM ($P = .85$), discharge FIM ($P = .65$), FIM efficiency ($P = .48$), and the proportion of admissions that were interrupted by a medical complication ($P = .18$).

Discussion

To our knowledge, this is the largest study to date that examines inpatient rehabilitation outcomes following heart and/or lung transplantation. Our findings support that multidisciplinary inpatient rehabilitation can significantly improve physical function and independence for debilitated transplant recipients. Nineteen percent of all heart and/or lung transplant recipients during the study period required inpatient rehabilitation, following a prolonged and complex acute hospital admission. Although complications and interruptions to rehabilitation were common following heart and/or lung transplantation, significant rehabilitation FIM gains were observed together with improvements in measures of mobility and endurance. Successful rehabilitation enabled 94% of the patient cohort to be discharged home to a private residence, supporting a role for multidisciplinary inpatient rehabilitation in these patient populations.

The improvements made by heart and/or lung transplant recipients in the present study compare favorably with published rehabilitation outcomes of other patient populations. An average FIM gain of 22 points is considered a clinically important change,[20] and is comparable in magnitude to improvements reported by national rehabilitation databases for large patient cohorts with debility[21] and neurologic conditions.[22] Similarly, mobility improvements in the present study well exceeded minimal clinically important differences reported for cardiopulmonary populations: 6MWT gains greater than 50 m are typically considered significant in most disease states[23,24] (here, improvements averaged 79.6 m); and Berg Balance Scale improvements of greater than 7 points are considered clinically meaningfull[25] (here, improvements averaged 18.2 points).

Table 4
Physiotherapy outcomes for a subset of 80 patients

Outcome measure	No. patients able to perform test at admission	Admission	Discharge	Improvement	*P* value
6-minute walk test (m)	58	103.6 ± 80.1	183.2 ± 104.8	79.6 ± 73.1 m further	<.001*
10-m walk (s)	61	25.3 ± 20.3	15.6 ± 12.9	9.7 ± 11.5 seconds faster	<.001*
Timed Up and Go (s)	54	26.4 ± 18.3	16.5 ± 14.1	9.9 ± 10.5 seconds faster	<.001*
Berg Balance Scale (score/56)	77	26.8 ± 17.1	45.0 ± 9.4	18.2 ± 11.6 point increase	<.001*

Data are presented as mean ± SD, and *P* value corresponds to change over time from admission to discharge. Improvements are seen as increased distance on the 6-minute walk, increased score on the Berg Balance Scale, and reduced time or fasting walker speed for the 10-m walk and Timed Up and Go.
*Indicates statistical significance.

Which Transplant Patients Require Rehabilitation?

In this study, 19.2% of all acute transplant recipients required admission to inpatient rehabilitation. This is consistent with earlier studies, suggesting that approximately 20% of all cardiopulmonary transplant recipients likely require inpatient rehabilitation.[15,26] Patients admitted to rehabilitation in the present study experienced significantly longer acute hospital admissions than their nonrehabilitation counterparts, including prolonged stays in the ICU and extended periods on mechanical ventilation. These factors likely contributed to their degree of debility at baseline, whereby FIM scores on admission to rehabilitation averaged 79.8 ± 20.3, indicting a need for assistance with most basic activities of daily living including dressing, bathing, grooming, transfers, and walking. By discharge, sufficient independence had been gained by nearly all patients (94%) to facilitate a safe discharge home to their private residence. Thus in this severely debilitated patient group, inpatient rehabilitation appears to be integral to restoring the strength and endurance needed to independently perform daily tasks and self-care.

Identifying the patient subpopulations likely to require inpatient rehabilitation following heart and/or lung transplantation is an important consideration. Dierich et al describe a German model-of-care whereby all lung transplant recipients receive 3 weeks of compulsory inpatient pulmonary rehabilitation.[27] They report improved physical functioning and quality of life following rehabilitation; however, their patient cohort appeared to be high functioning at baseline, with a median score on the Barthel index of 100 (where 100 represents a maximum score), and an average 6MWT distance of 370 m.[27] The authors note that inpatient rehabilitation is mandated due to a lack of outpatient services acutely after transplantation in Germany. Given suitable outpatient alternatives, it is likely that not all transplant patients will require intensive inpatient rehabilitation, but rather a select subgroup of particularly complex and/or debilitated patients.

In the present study, patients were specifically selected for inpatient rehabilitation on the basis of need, as indicated by their treating clinicians. In a similar setting, Tang and colleagues attempted to identify predictors of rehabilitation need among lung transplant recipients.[26] They found that advanced age, poor pretransplant 6MWT performance, the need for pretransplant mechanical ventilation, and a prolonged acute hospital length-of-stay were independent predictors of discharge to inpatient rehabilitation.[26] Our results support their observation that inpatient rehabilitation is often required following a prolonged acute hospital admission for lung and also for heart transplant recipients (see Table 1). Moreover, our findings suggest that measures reflective of postoperative care complexity, such as the amount of time spent in ICU or on mechanical ventilation, may also be useful to consider in future predictive models.

Unique Considerations for Transplant Rehabilitation

Consistent with previous studies, medical complications during rehabilitation were common among heart and/or lung transplant recipients, affecting 33% of admissions in the present study and typically 20% to 40% of reported admissions.[11,15,16] The majority of observed complications were respiratory in nature (including infections, pleural effusions, and acute respiratory distress), and although there appeared to be a slightly higher incidence of complications among lung compared to heart transplant recipients, this difference was not statistically significant. Despite the relatively high incidence of complications, it is important to note that the majority of patients were able to successfully complete their rehabilitation program once they were stabilized, and significant and clinically important FIM gains could still be made. These data provide support for the safety and feasibility of undertaking rehabilitation early posttransplant while also highlighting the need for vigilant patient monitoring and ongoing liaison with acute care transplant teams to ensure timely and appropriate management of complications as they arise.

A specialized approach to rehabilitation is required posttransplant that takes into account a variety of unique considerations specific to these patient populations. For all transplant cohorts, close liaison between the acute and rehabilitation transplant teams is essential to enable

seamless transition of patients from acute care to rehabilitation wards and back again as necessary. Immunosuppression needs to be considered and measures taken to minimize possible exposure to infection in shared therapy areas or class-based therapy sessions. Ongoing medical observation for signs of infection and regular blood and microbial screenings are needed to enable timely diagnosis and treatment of infective complications if they occur, and regular biopsies and graft imaging are also needed to monitor for signs of graft rejection.

Transplant rehabilitation needs to address patients' nutritional requirements[28] and medication side effects common to immunosuppressants and strong analgesics, such as nausea, tremors, bowel dysfunction, and/or fatigue, as these may interfere with the ability to participate in therapy.[11] Furthermore, adjustment counseling and other psychological therapy may be needed to address common psychological impacts of transplant for patients and their families, including feelings of "survivor guilt," anxiety, and depression associated with critical illness and the life-changing event of transplantation.[29]

Additional considerations specific to the heart and lung transplant populations have been outlined below:

Heart Transplant Rehabilitation

In the postoperative period, to avoid sternal nonunion, prolonged sternal precautions are required for heart transplant recipients in light of reduced bone healing. These may be adopted for up to 3 months, followed by a gradual increase in upper-extremity range of motion and resistance exercises.[15,30] Graded cardiovascular exercise is a critical component of heart transplant rehabilitation, but exercise sessions must be carefully structured with sufficient "warm up" and "cool down" time to compensate for chronotropic incompetence and delayed heart rate responses of the denervated heart.[31] In light of this, ratings of perceived exertion and/or direct metabolic measurements should be used to monitor exercise intensity, rather than heart rate responses.[30,32]

In a rehabilitation setting that offers care to patients before or after heart transplantation, specialist nursing skill may be required to manage patients with advanced assistive devices such as left ventricular assistive devices. Education of both staff and patients may also be needed regarding the management of assistive devices and complex drug regimens.

Lung Transplant Rehabilitation

Similar to heart transplant recipients, lung transplant recipients are typically managed with prolonged sternal precautions, and significant postoperative chest pain may need to be managed throughout rehabilitation.[11] Cough retraining and targeted respiratory muscle exercises can be used to improve secretion clearance and overcome the denervated cough reflex, phrenic nerve damage, and/or respiratory muscle weakness that often occur posttransplant.[5,11] Physiotherapy exercises may be used to address postural adaptations and altered patterns of breathing that may have developed, such as posture with kyphoses and/or shallow upper-chest breathing. Progression of strength, resistance and cardiovascular exercise training should also occur over the course of rehabilitation, with therapists monitoring patients for desaturation on exertion and reassessing supplemental oxygen requirements.[5]

Oropharyngeal dysphagia and altered gastroesophageal motility can both occur following lung transplantation, and increase the risk of aspiration, infection, and rejection.[33-35] Thus, involvement of a speech pathologist for assessment and management of these conditions is integral to rehabilitation following lung transplantation.[11]

Of note, no significant differences were observed between patients who received heart versus lung transplants in the present study. Although the content of their tailored rehabilitation programs varied, they demonstrated similar levels of functional improvement with rehabilitation, achieved over a similar length of stay.

Study Limitations

Limitations of this study include its retrospective study design and single rehabilitation cohort, without a formal comparator group. Although basic demographic comparisons were made between transplant recipients who did and did not receive inpatient rehabilitation, data on functional independence and mobility were not routinely available for nonrehabilitation patients. Without these data, it is difficult to draw strong conclusions about the specific efficacy of the rehabilitation component of a patient's care. In the future, it would be informative to directly compare functional independence and mobility outcomes of postoperative transplant recipients who did and did not receive inpatient rehabilitation, to better elucidate the effects of rehabilitation compared to the surgical transplantation procedure alone. It would also be useful to collect direct physiologic measures of cardiac, respiratory, and muscle function to elucidate possible mechanisms that may underlie improvements with rehabilitation. Nevertheless, this study's primary aim was to quantify clinical rehabilitation outcomes for the specialist heart-lung transplant patient population, of which we include the largest combined population to date.

This study only considered postoperative rehabilitation in the inpatient setting. In the future, it would be informative to compare outcomes for patients who received rehabilitation via other pathways, including inreach rehabilitation teams in the acute hospital and/or as outpatients via a day rehabilitation model. It would also be prudent to examine the effect of "prehabilitation" delivered prior to surgery, to reverse preoperative frailty where possible and improve postsurgical outcomes.[5,36,37] To build on the work of Tang and colleagues,[26] further research is needed to identify

predictors of rehabilitation needed in heart-lung transplant recipients, and to explore the optimal timing, doses, and durations of different rehabilitation models following cardiopulmonary transplantation.

Conclusions

Significant functional gains were achieved by debilitated heart and/or lung transplant recipients during multidisciplinary inpatient rehabilitation. Despite high baseline care needs and frequent medical complications, specialist transplant rehabilitation can be delivered successfully to patients following heart and/or lung transplantation and can result in improved physical function and help to restore patient independence.

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