Prehabilitation Coming of Age

IMPLICATIONS FOR CARDIAC AND PULMONARY REHABILITATION

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While cardiac and pulmonary rehabilitation programs traditionally involve exercise therapy and risk management following an event (eg, myocardial infarction and stroke), or an intervention (eg, coronary artery bypass surgery and percutaneous coronary intervention), prehabilitation involves enhancing functional capacity and optimizing risk profile prior to a scheduled intervention. The concept of prehabilitation is based on the principle that patients with higher functional capabilities will better tolerate an intervention, and will have better pre- and post-surgical outcomes. In addition to improving fitness, prehabilitation has been extended to include multifactorial risk intervention prior to surgery, including psychosocial counseling, smoking cessation, diabetes control, nutrition counseling, and alcohol abstinence. A growing number of studies have shown that patients enrolled in prehabilitation programs have reduced post-operative complications and demonstrate better functional, psychosocial, and surgery-related outcomes. These studies have included interventions such as hepatic transplantation, lung cancer resection, and abdominal aortic aneurysm (repair, upper gastrointestinal surgery, bariatric surgery, and coronary artery bypass grafting). Studies have also suggested that incorporation of prehabilitation before an intervention in addition to traditional rehabilitation following an intervention further enhances physical function, lowers risk for adverse events, and better prepares a patient to resume normal activities, including return to work. In this overview, we discuss prehabilitation coming of age, including key elements related to optimizing pre-surgical fitness, factors to consider in developing a prehabilitation program, and exercise training strategies to improve pre-surgical fitness.

Key Words: cardiorespiratory fitness • exercise training • surgery

In recent years, there has been increasing recognition of the value of cardiorespiratory fitness (CRF) as a marker of risk for adverse outcomes.[1] In fact, CRF has been repeatedly demonstrated to outperform traditional risk markers, including hypertension, smoking, and hyperlipidemia in terms of estimating risk for mortality and cardiovascular events.[1-5] This has led to the concept that CRF should be considered a risk factor of equal importance with these traditional risk factors and should be routinely measured or estimated, much like blood pressure, during clinical encounters.[1,6] Partly for these reasons, CRF is often the primary metric to gauge the efficacy of pharmaceutical, device, or rehabilitation therapies in patients with cardiovascular or pulmonary disease. Cardiorespiratory fitness is traditionally assessed following a cardiovascular event or interventions such as surgical, device, or exercise training. However, there has been a recent recognition that individual functional capabilities prior to surgical or other interventions powerfully predict outcomes associated with the intervention.[7-9] A growing number of studies have demonstrated that optimizing CRF before undergoing surgery has a considerable impact on health outcomes, both during surgery and in the short- and long-term period following surgery or other procedures.[7,10-13] This has led to the concept of "prehabilitation," a term that has been used in recent years to describe the process of enhancing a patient's functional capabilities to withstand a stressful event.[7,14]

Prehabilitation typically consists of 4- to 8-wk programs of exercise therapy along with related efforts to optimize patient risk status before surgery. This approach has been widely used in recent years outside the United States where there tends to be a much greater emphasis on prevention and rehabilitation.[15,16] Enhancing physical function through perioperative exercise programs has been demonstrated to improve outcomes among patients undergoing both cardiac and noncardiac surgery, including hepatic transplantation, lung cancer resection, abdominal aortic aneurysm (AAA) repair, upper gastrointestinal surgery, intra-abdominal surgery, bariatric surgery, and coronary artery bypass grafting (CABG).[8-14,17-28] Some notable studies in this area along with key results are outlined in Table 1.[22,29-38] Note that the application of prehabilitation to cardiac and pulmonary rehabilitation is relatively recent, and the benefits of prehabilitation have been shown to apply across the spectrum of chronic conditions. While the type and duration of the exercise interventions have varied, these studies have consistently demonstrated that enhancing physical function through programs of prehabilitation has a considerable impact on improving a wide range of outcomes, including surgical complications, length of hospitalization, and post-surgical exercise tolerance.

Similar to traditional cardiac rehabilitation, multifactorial approaches to prehabilitation have been shown to be most successful. While regular exercise and increasing functional capacity remain the foundation of these programs, there are a growing number of examples of the benefits of multidisciplinary approaches to improving outcomes associated with surgical interventions. For example, smoking cessation, psychosocial counseling, diabetes control, nutrition counseling, and alcohol abstinence have all been shown to improve perioperative outcomes.[39-42] A medical weight management period is typically required in guidelines assessing appropriateness for gastric bypass surgery, although this has generated some controversy.[43] Psychosocial prehabilitation has been demonstrated to be useful to provide realistic post-operative expectations, including return to work and pain management,[39,40] and can aid in smoking and alcohol

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Table 1

Selected Examples of Prehabilitation Studies in Patients With Different Clinical Conditions

Citation Year	Subjects	Procedure	Outcomes	Key Results
Arthur et al (2000)[29]	n = 249; ≥ 10 wk prehabilitation	CABG	Post-operative length of hospital stay, HRQOL	Reduced length of hospital stay; reduced length of ICU time; improved HRQOL pre- and post-surgery
Beaupre et al (2004)[30]	n = 131	Total knee arthroplasty	SF-36, strength measures, length of hospital stay	Reduced post-operative hospital stay
Carli and Zavorsky (2005)[31]	n = 275; various procedures, variable prehabilitation programs	Abdominal or cardiac surgery	Post-operative complications and death, length of stay, QOL, functional ability	Reduced post-operative complications and death, reduced length of stay, reduced decline in functional ability, improved QOL
Herdy et al (2008)[32]	n = 56; 6.7 ± 1.5 d of pre-operative progressive exercise training respiratory exercises included spirometer training and intermittent positive pressure breathing	CABG	6MWT, time to extubation, incidence of pulmonary complications and cardiac arrhythmias, length of hospital stay	Shorter time to endotracheal extubation; reduction in the incidence of pleural effusion, atelectasis, pneumonia, and atrial fibrillation or flutter, shorter length of in-hospital stay after surgery
Kim et al (2009)[33]	n = 21; 4-wk pre-operative aerobic exercise program	Colorectal cancer	Exercise capacity, 6MWT	Improved peak power output; improved ventilatory efficiency; improved 6MWT
Mayo et al (2011)[34]	n = 95; prehabilitation ~6 wk	Colorectal surgery	6MWT, QOL, exercise capacity	Improved exercise capacity; improved recovery responses and improved QOL
Nagarajan et al (2011)[35]	Meta-analysis	Lung resection	Exercise capacity, pulmonary function post-surgery	Improved exercise capacity; improved pulmonary function following surgery
Myers et al (2014)[22]	n = 140 AAA disease	AAA repair	Exercise capacity, AAA growth	Improved $\dot{V}O_{2peak}$, VT, ventilatory inefficiency
Grant et al (2015)[36]	n = 506; pre-operative CPX	AAA repair/EVAR	Mortality, exercise capacity	Improved 3-yr survival; increased exercise capacity; improved ventilatory efficiency
Barberan-Garcia et al (2018)[37]	n = 144; prehabilitation ~6 wk	Abdominal surgery	Post-operative complications, exercise capacity	Reduced post-operative complications, improved exercise capacity
Lotzke et al (2019)[38]	n = 118; 8-12 wk prehabilitation	Lumbar fusion surgery	QOL, physical function	Improved QOL and several measures of physical function

Abbreviations: 6MWT, 6-min walk test; AAA, abdominal aortic aneurysm; CABG, coronary artery bypass surgery; CPX, cardiopulmonary exercise test; EVAR, endovascular aneurysm repair; HRQOL, health-related quality of life; ICU, intensive care unit; QOL, quality of life; SF-36, Short Form 36 Health Survey Questionnaire; VT, ventilatory threshold; $\dot{V}O_{2peak}$, peak oxygen uptake.

abstinence. Smoking cessation >4 wk prior to surgery is associated with reduced risks of pulmonary complications, wound infections, and intensive care readmissions across a broad spectrum of surgical procedures.[41,42] Following is a discussion of key elements in optimizing pre-surgical CRF, factors to consider in developing a prehabilitation program, and exercise training strategies to improve pre-surgical CRF.

KEY ELEMENTS IN OPTIMIZING PRE-SURGICAL FITNESS

Knowing the CRF of an individual is fundamental before starting a prehabilitation program. This may take different forms depending upon the type of intervention. For example, it may mean improving peak oxygen uptake ($\dot{V}O_{2peak}$) in many patients, but in others the goal may be weight loss, improving other measures of physical function, reducing frailty, reducing fall risk, etc. Considering the goals to be achieved in approaching prehabilitation, it is reasonable to think in terms of three concepts. The first concept reflects the fact that many prehabilitation candidates, by definition, are particularly compromised. Thus, improving CRF in such patients mandates optimizing their readiness for more traditional, subsequent interventions targeting improved CRF. The second concept acknowledges the components of improved CRF as having both central (cardiopulmonary) and peripheral (oxygen delivery within skeletal muscle) components. Third, improving muscular fitness should complement any cardiorespiratory exercise prescription. In patients with particularly limited exercise tolerance where traditional approaches to improving CRF are compromised, a program that targets muscular fitness may be especially important.

The first concept, improving CRF in patients with especially compromised function mandates optimizing patient readiness for more traditional interventions targeting improved CRF, is frequently overlooked. That is, there are physiological parameters that are fundamental to facilitating improved CRF, and these are often presumed to be either within normal ranges or optimized in traditional populations availed for exercise training. Assessment considerations for patients awaiting surgery and who are appropriate for a prehabilitation intervention are noted in Table 2. In addition to ensuring the considerations listed in Table 2 are included in the pre-exercise evaluation, other important elements to consider in a prehabilitation

Table 2

Pre-exercise Considerations in Prehabilitation

Laboratories that influence the exercise response and adaptation (hemoglobin, hematocrit)
Medications, including supplemental oxygen, that influence the exercise response
Resting vital signs
Symptoms and cognition to ensure accurate responses during exercise
Pre-exercise auscultation and assessment of breathing mechanics
Musculoskeletal and balance screening, manual muscle testing to identify specific weaknesses that might impair exercise
Coexisting diagnoses that may influence the exercise approach (lung dysfunction, peripheral arterial disease)

approach may include less well-recognized strategies that are particularly well-suited for those with low CRF.

One such strategy to consider is the use of nonexercise session energy-saving techniques to optimize energy for focused exercise therapy sessions, such as the use of assistive and adaptive equipment. Likewise, it is appropriate to plan daily activities that interpose frequent rest periods to conserve energy and metabolic resources needed for therapy. Another important pre-exercise strategy is ensuring optimal oxygen exchange, including breathing exercises (diaphragmatic, pursed lip) and/or devices such as incentive spirometry to promote greater lung volume, improve distribution of ventilation and more efficient breathing patterns. It is important to recognize the interprofessional collaboration of respiratory therapy and nursing, for example, in a team approach to optimize airway clearance techniques and breathing exercises. In particular, an interprofessional approach for patients in whom airways are compromised by pulmonary comorbidities, including as indicated, airway clearance techniques (postural drainage, manual or assisted therapy to remove secretions) to reduce risk of atelectasis and improve ventilation through decreased airflow obstruction, is critical.

The second important concept is the acknowledgment that the components of improved CRF are both central and peripheral in nature. Central limitations are a function of diminished cardiac output, but there is a poor correlation between CRF and ejection fraction, so reduced ejection fraction should not bias the opportunity to improve CRF. In many chronic conditions, peripheral adaptations provide the greatest contribution to improved CRF and function; thus, designing endurance interventions that are multimodal and target a variety of upper extremity and lower extremity muscle groups is critical. An important parallel consideration, particularly in lower functioning patients, is the premature fatigue associated with upper extremity exercise. In the development of a prehabilitation exercise therapy plan, it is appropriate to add upper extremity training (arm ergometry, for example), but the ventilatory requirement combined with low relative endurance reserve in the upper extremity can impair achieving the objectives of the broader prehabilitation plan.

The third concept is the recognition that muscular fitness should complement any cardiorespiratory exercise prescription. This is especially relevant when the ability to engage in moderate-intensity cardiorespiratory exercise programming is significantly reduced, as it often is in patients awaiting surgery and who may be quite sedentary. For patients with significantly compromised CRF, interventions designed to improve muscular fitness may be as important to cardiorespiratory function as traditional cardiovascular exercise modes. In this regard, one set of a muscular fitness regimen (elastic bands, hand weights, or circuit) is sufficient to improve measures of muscular fitness. Moreover, multiple, shorter bouts of exercise, balancing aerobic challenges with muscular fitness exercises, are vital.

STRATEGIES TO IMPROVE FITNESS PRIOR TO A SURGICAL OR OTHER INTERVENTION

With the aging of society, care of patients after cardiac surgery has become more complex due to the increasing number and severity of comorbidities, frailty, and psychosocial factors. Many of these factors are controllable and even reversible if detected and treated in a timely fashion. One cornerstone of efforts to manage these comorbidities is incorporating strategies to improve CRF. The pre-surgical period provides one such opportunity to enhance CRF and help control the severity of many of these comorbidities. There are many appropriate strategies to achieve these goals; importantly, the fundamentals of exercise prescription are similar for prehabilitation and rehabilitation, and the approach should be individualized depending upon the patient, the type of intervention, and comorbidities present.

Exercise training appropriately remains the cornerstone of modern cardiac rehabilitation, since it not only counteracts the major modifiable risk factor physical inactivity but also because it favorably affects the spectrum of modifiable cardiovascular disease risk factors including overweight and obesity, arterial hypertension, dyslipidemia, hyperglycemia, and smoking.[44] As a consequence, exercise training ameliorates symptoms, reduces ischemia, improves endothelial function,[45-47] induces regression or attenuation of progression of coronary artery disease,[48-51] and reduces morbidity and mortality.[52] This is manifested in current guidelines and position papers from all major cardiac societies.[53-56] Prehabilitation should be considered a catalyst that provides the beginning steps in achieving these goals. Prehabilitation is more than simply an early exercise training program in that it represents not just exercise training, but the coordinated sum of efforts needed to establish the best possible physical, psychological, and social conditions that help limit the untoward effects of surgery and enable patients to reclaim their familiar place in society as soon after surgery as possible. Much like cardiac rehabilitation programs, effective prehabilitation is conducted by an interdisciplinary team that aims to achieve a sustainable reduction in cardiovascular risk factors, helps restore physical function, and addresses psychosocial issues (eg, anxiety, depression, and return to work) that are inevitably associated with surgical interventions.

More than a decade ago, Herdy et al[32] identified a critical window of opportunity for enhancing function prior to CABG. Frequently, the decision to perform CABG is made while patients have been admitted because of an acute coronary event or routine coronary angiography, which revealed coronary artery disease too severe to permit discharge before surgery. In these and other situations, patients remain in the hospital until surgery can be safely performed. As a consequence patients are at risk of deconditioning, which is known to negatively affect surgical outcomes. The hypothesis was tested that cardiopulmonary prehabilitation is superior to usual care in reducing post-operative complications and hospital length of stay.[32] In order to make better use of this waiting period, patients were enrolled in a phase I in-hospital rehabilitation program, which consisted of $\geq$ 5d of a pre-operative exercise program. The intervention started on the day of admission and was paused only for surgery until the day of extubation, when it was continued again until the day of hospital discharge. The exercise protocol consisted of progressive exercises according to standardized phase I cardiac rehabilitation programs and progressed from passive movements on the first post-operative day to walking at an intensity of 2 metabolic equivalents (METs) and climbing two flights of stairs on the fifth day ($\approx$4 METs). Additional respiratory exercises included spirometer training and intermittent positive pressure breathing. Patients in the control group received usual care. Participation in the program of prehabilitation for a mean of just 6.7 $\pm$ 1.5 d led to shorter time to endotracheal extubation, reductions in the incidence of pleural effusion, atelectasis, pneumonia, atrial fibrillation or flutter, and shorter length of in-hospital stay after surgery. Thus, prehabilitation was safe and patients showed improvements in each of the key metrics related to CABG. This study in part laid the foundation for numerous subsequent studies that have consistently confirmed the postulated benefits of prehabilitation. Indeed, Sandhu and Akowuah[57] recently reviewed four meta-analyses on prehabilitation associated with cardiac surgery and reported an overall reduction in post-operative pulmonary complications and reductions in length of stay, with no adverse events or differences in mortality as compared to control groups not receiving pre-habilitation.

The group of patients undergoing CABG described earlier is just one example of a population who may benefit from prehabilitation. Strategies to improve CRF should be individualized to the type of surgical intervention and the patient. For example, patients awaiting orthopedic surgery are inevitably required to learn to walk with crutches, and therefore these patients benefit from enhancing strength in the pre-surgical period to optimize post-surgical ambulation. A growing number of studies have shown that prehabilitation prior to orthopedic surgery accelerates the return to normal physical function, potentially hastening the capacity to return to work.[20,24,27] Similar to patients with stable coronary artery disease with or without stable angina, patients awaiting orthopedic surgery could join classes of aerobic exercise training as well as resistance training to increase their CRF prior to surgery and thus improve their prognosis. In addition, it has previously been shown that continuous and interval training were equally effective in patients with coronary artery disease.[58] The medical team must assure that the mode of exercise is appropriate for a given patient but may consider either or both of these training protocols. Moreover, a considerable body of data is available supporting the benefits of exercise training among nonrevascularized patients with stable myocardial ischemia.[48] It can be safely stated that on average patients fared well with submaximal aerobic exercise training that not only included cycle ergometer training but also jogging, ball games, and swimming. Provided that exercise training is individually tailored, patients can be offered a wide choice of exercises that can safely be performed prior to revascularization.

SUMMARY

Prehabilitation is comparatively new and its value is not widely recognized in the clinical community. For example, although optimizing physical function in preparation for surgery has been recommended in many surgical guidelines (examples shown in Table 3),[59-63] the term prehabilitation does not appear in these guidelines. The term is not yet part of the lexicon in clinical medicine, particularly in the United States. As outlined earlier, preparing patients for the stress of major surgery by initiating the recovery process before surgery and optimizing pre-operative CRF has been shown to have numerous benefits, including lower operative morbidity and mortality, shorter hospitalization, and more rapid recovery from surgery. Importantly, recent data also suggest that participants in pre-surgical exercise programs are more likely to participate in post-surgical rehabilitation programs, which remain demonstrably underutilized. While randomized trials are lacking, optimizing physical function prior to a surgical intervention in addition to a standard rehabilitation program post-surgery would undoubtedly result in further improvements in function, quality of life, and more rapid return to work for the majority of patients.[64,65] Similar to traditional rehabilitation, prehabilitation programs have been successfully performed using telehealth, resulting in lower costs and improved compliance.[65,66] An important development would be recognition by the Centers for Medicare & Medicaid to formalize reimbursement for prehabilitation programs.

In addition to improvements in physical function, prehabilitation programs have been shown to reduce the degree of emotional distress associated with major surgery, improve quality of life, and reduce disability during the post-surgery phase.[8-14,17-38,64-67] Expectations should be modest given that many patients who have reached the point where surgery is required have end-stage disease and are refractory to other treatments. For some patients, symptoms will limit exercise intensity, and many patients with conditions such as peripheral arterial disease, AAA, or cancer may be elderly and frail.[68] More research is needed to determine the safety of prehabilitation programs for these patients, and cost-effectiveness studies are lacking. Nevertheless, given the growing body of data documenting the benefits of prehabilitation, such programs should be routinely considered as part of surgical interventions in appropriate patients. All patients considered for surgery would prefer to spend less time in the hospital, return to their occupation or regular life more rapidly and have fewer complications, and prehabilitation generally provides these benefits. Finally, given what we have learned in recent years regarding the powerful impact of CRF on health outcomes,[1-7] prehabilitation provides an ideal period to educate patients. Patients not only gain the benefits of prehabilitation, but a healthy habit of regular physical activity will ideally continue after surgery. Any segment of the population that incorporates more regular physical activity will very likely improve the health of that population.[1-6,67,69-71]

Table 3

Examples of References to Optimizing Pre-surgical Physical Function in Surgery Guidelines

- American College of Chest Physicians Clinical Practice Guidelines[58]
  - For lung resection, with $\dot{V}O_{2peak} > 20$ mL/kg/min surgical risk is minimal; for those <10 mL/kg/min (or $<35\%$ age-predicted $\dot{V}O_{2peak}$) perioperative risk is high and patients should be counseled regarding nonsurgical options
- ACC/AHA Guidelines for Perioperative Assessment[59]
  - Patients able to demonstrate a functional capacity of ≥ 4 METs may safely proceed to surgery without further cardiac assessment
- Society for Vascular Surgery Practice Guidelines for abdominal aortic aneurysm (AAA)[60]
  - During surveillance, management should include counseling that moderate activity does not precipitate rupture and may limit AAA growth rate
- Enhanced Recovery After Surgery (ERAS) Society and the European Society of Thoracic Surgeons guidelines[61]
  - Pre-operative exercise programs recommended to reduce hospital length of stay and post-operative pulmonary complications
- ERAS for Gastrointestinal Surgery: Consensus Statement for Anesthesia Practice[62]
  - Patients should be encouraged to increase their physical activity in the pre-operative period

Abbreviations: MET, metabolic equivalent; $\dot{V}O_{2peak}$, peak oxygen uptake.

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