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Prehabilitation clinic in cardiac surgery: multidisciplinary protocol for the improvement of postoperative outcomes

Giuseppe Santarpino[1,2,3*], Veronica D'Anna[2], Chiara Maria Prencipe[1], Monica Cavone[4], Giulia Palisi[4,5], Michela Francia[2,6], Silvia Patera[6], Nadia Nestola[2], Luana Maniglio[2], Emanuele Verghi[2], Luigi Specchia[2], Alessandro Fiorentino[2], Valeria Cosco[7], Marta Calassanzio[8], Serena Arima[9], Raffaele Barbato[10] and Giuseppe Speziale[11]

Abstract

Background Prehabilitation in cardiac surgery is a multidisciplinary approach aimed at optimizing the clinical and functional status of patients awaiting elective procedures. Interventions addressing nutrition, physical activity, psychological support and comorbidity management may improve postoperative outcomes, reduce complications and accelerate recovery. Despite its potential, prehabilitation in cardiac surgery remains scarcely explored and not routinely implemented.

Objectives The primary objective is to evaluate the impact of a multidisciplinary prehabilitation program in patients undergoing elective cardiac surgery. The study will assess its effect on perioperative clinical outcomes, including the number of red blood cell units transfused from surgical incision until hospital discharge (primary outcome), as well as duration of postoperative mechanical ventilation (hours), length of stay in the intensive care unit and ward (days), total hospital length of stay and the incidence of hospital-acquired infectious complications.

Methods This single-center prospective observational study includes a historical control group. Adult patients undergoing elective cardiac surgery at Città di Lecce Hospital, GVM Care & Research, will be consecutively enrolled over six months. Outcomes will be compared with patients treated during the corresponding period of the previous year.

Expected results We hypothesize that a proportion of patients within the study sample will present with unrecognized iron deficiency and that its correction may reduce the number of perioperative red blood cell units administered. Respiratory training, smoking cessation and controlled physical activity with telemedicine monitoring may be associated with shorter postoperative intubation time. Nutritional supplementation, especially in frail patients, is expected to improve immune competence and reduce surgical site infections. Psychological support may improve adherence and decrease surgery withdrawal while on the waiting list. An economic analysis will assess the feasibility of institutionalizing this clinic in both hospital and online settings.

*Correspondence:
Giuseppe Santarpino
santarpino@unicz.it

Full list of author information is available at the end of the article

Conclusion This study may provide evidence supporting prehabilitation as a means to improve perioperative clinical outcomes in cardiac surgery. Positive results could pave the way for systematic implementation of a tele-prehabilitation platform, enabling remote participation and representing an evolution of the perioperative care model.

Trial registration This study protocol has been approved by the local Ethics Committee of Bari (Study ID: 2717/CEL). Registration on ClinicalTrials.gov is ongoing.

Keywords Prehabilitation, Cardiac surgery, Nutrition, Psychology, Exercise, Telemedicine

Background

In recent years, cardiac surgery has been characterized by a progressive increase in the average age of patients and in the prevalence of comorbidities, making this population particularly frail and at higher risk of postoperative complications, prolonged hospitalization and impaired functional recovery [1, 2]. Currently, the preoperative approach focuses primarily on assessing surgical risk and optimizing clinical conditions. However, this strategy does not contribute to enhancing the patient's overall resilience, either from a physical or a psychological perspective [3].

Over the past decade, the perioperative approach in surgery has evolved with the introduction of Enhanced Recovery After Surgery (ERAS) protocols, which aim to reduce surgical stress, optimize functional recovery and improve clinical outcomes. Although initially developed for abdominal surgery, these protocols have been progressively adapted to other fields, including cardiac surgery, where interest in their application is steadily increasing. In this context prehabilitation, defined as the functional, nutritional and psychological optimization of the patient in the weeks preceding surgery, emerges as a consistent extension of ERAS principles. Although not yet formally standardized within ERAS guidelines for cardiac surgery, this preparatory phase is fully aligned with the multimodal and proactive approach promoted by the protocol, which advocates for comprehensive and individualized preoperative management, particularly in frail patients or those with severe comorbidities [4].

Targeted interventions on nutrition, physical exercise and emotional support aim to enhance the patient's physiological and psychological reserves, transforming the preoperative period into an active phase of comprehensive preparation rather than a passive waiting period. Prehabilitation has already been explored in several medical specialties, with promising results in terms of reducing postoperative complications, shortening hospital stay, improving functional recovery and increasing patient quality of life [5–7]. Its application in cardiac surgery, however, remains poorly standardized [8]. Nevertheless, the underlying principles - improvement of physical performance, nutritional status, and psychological well-being - are equally relevant in patients undergoing major cardiac surgery, who are well known to be frail and at high risk.

In light of this evidence, the establishment of a prehabilitation clinic in cardiac surgery represents a concrete opportunity to implement an innovative and personalized care model that fosters genuine integration among the various professionals involved in patient care (cardiac surgeons, physiotherapists, nutritionists, psychologists). Its implementation may constitute a pivotal step toward significantly improving clinical outcomes, enhancing the economic sustainability of the healthcare system and, most importantly, increasing the quality of life of patients undergoing elective cardiac surgery.

Our pilot prehabilitation clinic in cardiac surgery, based at Città di Lecce Hospital, GVM Care & Research, provides a structured approach to preoperative care in Southern Italy.

This program is initiated ideally one month before surgery to ensure sufficient time for the interventions to be effective. These include the assessment and optimization of nutritional status, physical and respiratory exercise, and psychological and behavioral support, aimed not only at reducing preoperative anxiety and stress, but also at promoting greater awareness and correcting any unhealthy habits.

The adoption of a structured preoperative prehabilitation program may contribute to improved perioperative clinical outcomes in patients undergoing elective cardiac surgery, including reduced transfusion burden, shorter duration of mechanical ventilation, decreased length of hospital stay and lower incidence of postoperative complications. These benefits, stemming from more adequate physical and psychological preparation of the patient, may also contribute to reduced healthcare costs and a faster, more effective and sustainable postoperative recovery, particularly through the transformation of this physical clinic into a hybrid physical-virtual model.

Methods

Study design

This is a single-center prospective observational study with a historical control group, conducted at Città di Lecce Hospital, GVM Care & Research, Lecce, Italy. The aim is to evaluate the impact of a multidisciplinary

preoperative prehabilitation program on patients scheduled for elective cardiac surgery. The study has been designed in accordance with the SPIRIT (Standard Protocol Items: Recommendations for Interventional Trials) guidelines.

The study design includes a comparison between two cohorts: a prospective cohort of patients participating in the prehabilitation program and a historical control cohort (Fig. 1).

The intervention group will consist of consecutively enrolled patients over an approximate 6-month period starting after ethics approval. The control group will consist of patients with comparable characteristics who underwent major cardiac surgery at the same center during the corresponding 6-month period of the previous year, in order to minimize potential seasonal bias.

These patients will not have received any structured prehabilitation intervention prior to surgery. Selection will be based on comparable clinical and surgical criteria, particularly regarding the type of cardiac procedure. While identical feasibility criteria cannot be retrospectively applied, baseline comparability between groups will be carefully assessed.

Participants

All patients placed on the waiting list for cardiac surgery over an approximate 6-month period will be assessed for eligibility for inclusion in the study. Written informed consent for data collection and analysis will be obtained after providing adequate information to the patient.

Eligibility criteria

Inclusion criteria:

- Age ≥ 18 years
- Scheduled for major elective cardiac surgery performed under cardiopulmonary bypass

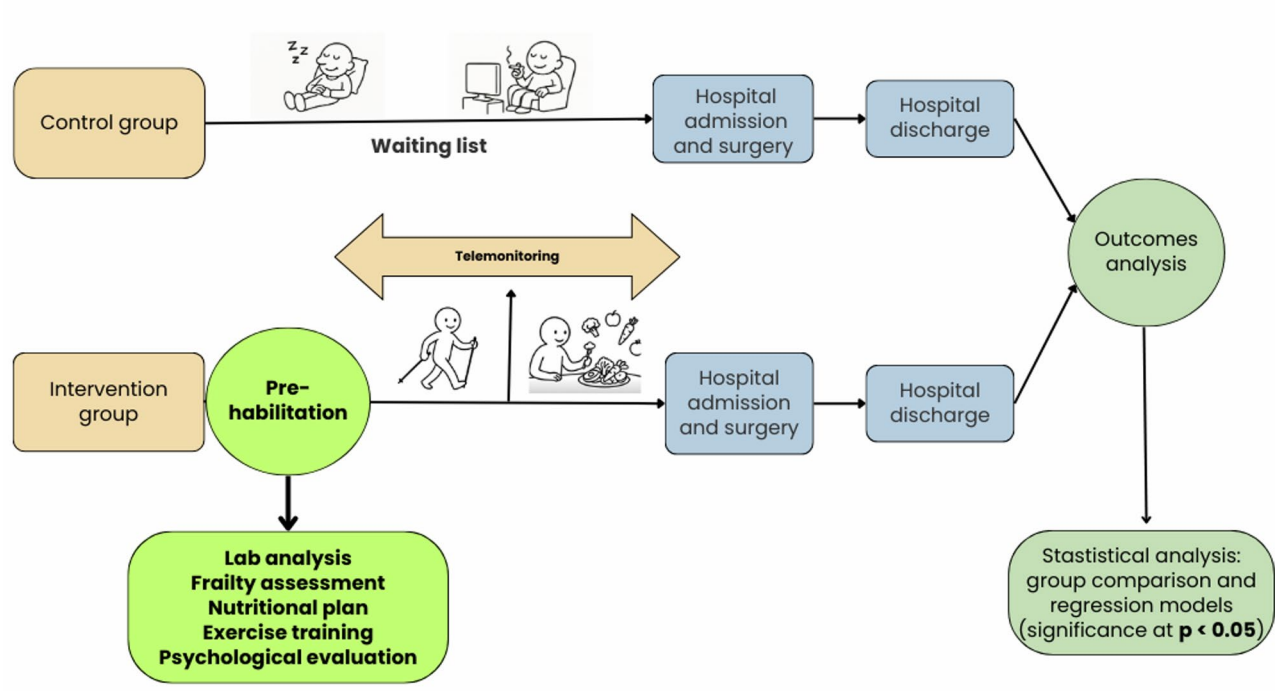

Fig. 1 Flowchart of the prehabilitation clinic pathway.Schematic representation of the single-center prospective observational study comparing patients undergoing a multidisciplinary prehabilitation program with a historical control group. The intervention includes nutritional, physical, and psychological optimization with telemonitoring during the preoperative waiting period, followed by hospital admission, cardiac surgery and discharge. Postoperative outcomes are subsequently analyzed and compared between groups

(irrespective of surgical access, including full sternotomy or minimally invasive approach)

Exclusion criteria:

- Urgent or emergency surgery
- Patients undergoing coronary artery bypass grafting (CABG) or transcatheter procedures (TAVI)
- Non-adherence or inability to complete the prehabilitation program due to cognitive, social or physical limitations
- Medical contraindications precluding safe participation in all components of the prehabilitation program
- Refusal to provide informed consent for data processing

Recruitment and enrollment procedure

Patients will be identified among those placed on the waiting list for elective cardiac surgery at the private hospital Città di Lecce Hospital, GVM Care & Research. They will be contacted by telephone by members of the clinical research team to propose participation in the study and to schedule a prehabilitation visit. It should be noted that the waiting time for surgery in both the historical and study groups is approximately one month. Participation in the prehabilitation program will in no way alter or prolong this timeframe. In other words, if a patient requires surgery sooner, they will undergo the procedure as scheduled.

During the outpatient visit, held at the center's prehabilitation clinic, the patient will receive detailed information about the study and the proposed program and will be asked to sign written informed consent for the collection and processing of clinical data, in accordance with current regulations (EU Regulation 2016/679 – GDPR).

During the same visit, eligibility will be assessed according to clinical criteria by the multidisciplinary team, consisting of a clinical project coordinator, a cardiac surgeon, a nutritionist, a physiotherapist and a psychologist. Frailty status, nutritional and psychological assessments will not be used as eligibility criteria for inclusion in the prehabilitation program, but will be systematically performed in all enrolled patients to tailor and personalize the intensity and components of the intervention.

For the transition to telemedicine management and for performing physical activity using dedicated devices, the patient will also be instructed on how to download and use the app developed for remote monitoring of the exercise component.

Interventions

During the visit, a complete medical history will be collected, with particular attention to comorbidities and frailty status. The latter will also be assessed using a specific frailty assessment tool, the Clinical Frailty Scale (CFS) [9]. This will be followed by an analysis of dietary habits and lifestyle, including physical activity level, alcohol consumption and smoking habits.

The patient will undergo anthropometric assessment, including measurement of weight, height and body circumferences (waist, umbilical, hip, biceps and calf), calculation of body mass index (BMI), and nutritional risk screening. Nutritional screening will be performed using the Malnutrition Universal Screening Tool (MUST) [10] in patients younger than 65 years and the Mini Nutritional Assessment (MNA) [11] in patients aged 65 years or older. Both tools are validated instruments for identifying risk of malnutrition and stratifying patients according to nutritional status. In addition, a bioelectrical impedance analysis will be performed to estimate body composition.

From a functional perspective, the patient will undergo the Short Physical Performance Battery (SPPB) [see Additional file 3], a validated and widely used tool for the assessment of lower extremity function and physical performance. The SPPB evaluates balance, gait speed and chair stand performance [12].

The patient will then be provided with a Tri-Flow device, along with appropriate instructions for home use (5–6 times daily, 3–4 repetitions), aimed at strengthening respiratory muscles, as well as the necessary equipment for performing home-based physical activity monitored via telemedicine (Gabel *e*-Poles) [see Additional file 4]. The exercise component consists of unsupervised, home-based, low-intensity aerobic training and mobility exercises. Patients will be instructed to perform daily aerobic activity in the form of walking with e-Poles for approximately 30 min. No structured resistance training will be prescribed in the preoperative phase. Exercise intensity will be maintained at a low level and individualized based on the patient's clinical condition and symptom tolerance, with particular attention to signs such as breathlessness, fatigue, pain or other cardiac-related limitations. Training will be adapted or temporarily suspended in the presence of limiting symptoms. Physical activity will be remotely monitored through the e-Poles device and a dedicated app, allowing tracking of activity parameters and supporting training safety.

The psychological component includes baseline screening through administration of the Hospital Anxiety and Depression Scale (HADS) (Table 1), followed by a supportive interview aimed at identifying surgery-related concerns and reducing preoperative anxiety. HADS results will be used to tailor the intensity of psychological

Table 1 Hospital Anxiety and Depression Scale (HADS)

Question	Option 1	Option 2	Option 3	Option 4
I feel tense or 'wound up'	Most of the time	A lot of the time	From time to time, occasionally	Not at all
I still enjoy the things I used to enjoy	Definitely as much	Not quite so much	Only a little	Hardly at all
I get a sort of frightened feeling as if something awful is about to happen	Very definitely and quite badly	Yes, but not too badly	A little, but it doesn't worry me	Not at all
I can laugh and see the funny side of things	As much as I always could	Not quite so much now	Definitely not so much now	Not at all
Worrying thoughts go through my mind	A great deal of the time	A lot of the time	From time to time, but not too often	Only occasionally
I feel cheerful	Not at all	Not often	Sometimes	Most of the time
I can sit at ease and feel relaxed	Definitely	Usually	Not often	Not at all
I feel as if I am slowed down	Nearly all the time	Very often	Sometimes	Not at all
I get a sort of frightened feeling like 'butterflies' in the stomach	Not at all	Occasionally	Quite often	Very often
I have lost interest in my appearance	Definitely	I don't take as much care as I should	I may not take quite as much care	I take just as much care as ever
I feel restless as if I have to be on the move	Very much indeed	Quite a lot	Not very much	Not at all
I look forward with enjoyment to things	As much as I ever did	Rather less than I used to	Definitely less than I used to	Hardly at all
I get sudden feelings of panic	Very often indeed	Quite often	Not very often	Not at all
I can enjoy a good book or radio or TV program	Often	Sometimes	Not often	Very seldom

The table reports the 14 items of the questionnaire, divided into two subscales: Anxiety (odd-numbered items) and Depression (even-numbered items). Each item is scored from 0 to 3, according to the response selected, for a maximum of 21 points per subscale. Scores are interpreted as follows: 0–7 = normal, 8–10 = borderline abnormal, ≥ 11 = abnormal. Higher scores indicate greater symptom severity. The questionnaire is administered to patients enrolled in the prehabilitation program during the preoperative assessment phase

Table 2 List of laboratory blood tests prescribed to assess and optimize the patient's nutritional status before cardiac surgery

Complete blood count
Blood glucose and glycated hemoglobin
Serum albumin
Serum iron, ferritin, transferrin, vitamin B12, folic acid
Creatinine, sodium, potassium, calcium, chloride
GOT, GPT, vitamin D
PCR, VES
Triglycerides, total cholesterol, LDL, HDL

The tests are performed at baseline in patients enrolled in the prehabilitation program during the preoperative assessment phase

support and additional consultation sessions may be offered when clinically indicated.

Finally, blood tests will be requested to identify any nutritional deficiencies (Table 2).

As part of the prehabilitation pathway, patients will undergo early screening for anemia and iron deficiency during the initial preoperative assessment, which is ideally performed four weeks before the planned surgical procedure. Laboratory evaluation includes hemoglobin, transferrin saturation, serum iron and ferritin levels, with additional testing (vitamin B12 and folic acid).

Identified deficiencies will be managed according to a standardized, clinically driven approach consistent with patient blood management principles. In patients with mild iron deficiency or borderline anemia and adequate time before surgery, dietary counseling and oral iron supplementation may be considered, provided that treatment is tolerated. In the presence of more significant deficiency, limited time to surgery, impaired absorption, or need for more rapid optimization, intravenous iron supplementation will be considered according to institutional practice and prescribing clinician judgment. This approach aims to optimize preoperative hematologic status as part of the multidisciplinary prehabilitation program, without altering established perioperative transfusion thresholds or clinical decision-making. Transfusion practice at our institution follows stable patient blood management protocols that remained unchanged across the historical and intervention periods. Perioperative red blood cell transfusion is guided by predefined hemoglobin thresholds and clinical criteria, which were consistently applied throughout the study timeframe.

Based on the results of the overall nutritional assessment, each patient will receive a personalized dietary plan developed by the clinical nutritionist as part of the multidisciplinary team. The nutritional intervention is offered to all enrolled patients and tailored to their individual needs, with the aim of optimizing nutritional status during the preoperative period.

Dietary plans will be structured according to a modular model, organized into independent and interchangeable days throughout the week. For each meal, multiple

alternatives will be offered within each main food category, with quantities defined to ensure caloric equivalence and comparable macronutrient composition across different options. The final section of the dietary plan will be dedicated to practical comments and recommendations to facilitate correct interpretation and implementation of the nutritional program. This section will include a list of iron-rich foods to be prioritized among the proposed alternatives, as well as general and individualized guidance based on clinical conditions, laboratory abnormalities, and ongoing pharmacological therapy, to ensure a targeted nutritional intervention and prevent potential drug–nutrient interactions.

When necessary, specific supplements from the Essecore® line may be prescribed to correct the identified deficiencies. These may include *Nitronat Plus*, with vitamins (C, E, B-group), *Lactobacillus rhamnosus*, nucleotides, minerals, amino acids and hydrolysed whey proteins to promote energy metabolism and restore gut microbiota balance; *Omegacor Plus*, containing omega-3 fatty acids (EPA, DHA) to support cardiovascular health; *Ferrocor Plus*, a dietary supplement based on iron and vitamins to help reduce tiredness and fatigue; *Benecis*, with alpha-lipoic acid, choline, arginine alpha-ketoglutarate and vitamins B1, B3, B6, B12 and D3 for energy production, nervous system function and antioxidant defence and *Magcor*, formulated with magnesium, potassium, zinc and vitamin C to contribute to electrolyte balance and muscle function.

All patients will also receive behavioral recommendations to follow during the preoperative period, including: discontinuing alcohol consumption and cigarette smoking; avoiding prolonged fasting in the days preceding surgery; taking supplements containing omega-3 fatty acids, vitamin C and L-arginine, even in the absence of documented deficiencies, to support immune function.

The prehabilitation program is modular and individualized. When specific components are contraindicated, patients will receive the remaining components considered safe.

Timeline and assessments

The program includes an initial outpatient visit ideally scheduled 30 days prior to the planned cardiac surgery. In routine practice, a minimum exposure of approximately two weeks is considered feasible and is generally targeted. Given the variability of surgical scheduling, actual prehabilitation exposure duration may vary; duration will be recorded and accounted for in the statistical analysis. During this visit, all clinical, nutritional, functional and psychological assessments outlined in the protocol will be performed.

Patients will be monitored weekly using a structured online questionnaire (Google Forms) addressing all components of the prehabilitation program, including nutritional adherence, physical activity, respiratory exercises and psychological well-being. During these check-ins, any issues or difficulties can be discussed via teleconsultation and the intervention, particularly the dietary plan, may be adjusted as needed to better accommodate individual requirements.

Based on the needs identified during the initial evaluation and through the weekly questionnaire, patients may be offered an additional psychological support pathway, with possible follow-up sessions scheduled before surgery.

A final assessment of overall compliance, together with key clinical and anthropometric parameters (including body circumferences and bioelectrical impedance analysis), will be performed on the day of hospitalization to document any interval changes during the preoperative period.

During the index hospitalization, data will be collected to assess the outcomes of interest. Specifically, information on the number of red blood cell units transfused from surgical incision until hospital discharge, duration of postoperative mechanical ventilation, length of stay in the intensive care unit and in the ward, total hospital length of stay and the incidence of surgical site infections will be recorded.

Data collection and management

Clinical data for patients in the control group will be collected retrospectively through the review of medical records, anesthesiology charts and surgical logs available in the archives of Città di Lecce Hospital - GVM Care & Research.

All patient data will be anonymized. Relevant study information will be stored in secure databases accessible only to authorized personnel. Data management will comply with Regulation (EU) 2016/679 (GDPR) and current Italian legislation on the protection of personal data.

Primary and secondary outcomes

The primary outcome of the study will be the number of red blood cell units administered from surgical incision until hospital discharge.

Secondary outcomes, in order of relevance to the study objectives, will include: duration of postoperative mechanical ventilation (hours), length of stay in the intensive care unit (days), length of stay in the ward (days), total length of hospital stay (days) and incidence of surgical site infections.

Statistical analysis

The data will be transferred to the R software for statistical analysis. Fisher's test, Student's test as well as non-parametric tests will be involved to calculate statistical

significance and assess significant differences in the compared groups according to each outcome of interest. All inferential analyses will be reported with exact p-values and corresponding 95% confidence intervals. P-values < 0.05 will be considered statistically significant. Associations between variables will be evaluated with correlation coefficients as well as with association indices such as chi-square or eta index depending on the variable characterization. Multiple regression analyses will be performed for the validation of risk variables, adjusting for baseline risk factors.

The number of red blood cell units transfused (primary outcome) will be modeled using multivariable regression models appropriate for count data, depending on distributional assumptions and model diagnostics, adjusting for baseline confounding factors. Effect estimates will be reported with corresponding 95% confidence intervals.

Risk variables will initially be explored in univariate analyses for each end-point and subsequently included in multivariable models based on clinical relevance and statistical considerations. With respect to the secondary outcomes, duration of postoperative mechanical ventilation (hours) will be analyzed as a continuous variable using multivariable regression models, adjusting for relevant baseline confounders. The incidence of surgical site infections will be modeled with logistic regression. The total length of hospital stay and the number of days spent in the intensive care unit and in the ward will be studied with multiple Poisson regression accounting for confounding factors. Item response models will be involved to evaluate questionnaire results and to estimate latent traits such as psychological well-being of the patients.

Given the observational design with a historical control group, propensity score methods will be applied to account for potential baseline imbalances between groups.

Discussion

A significant proportion of patients scheduled for major cardiac surgery present, already in the preoperative phase, with clinical frailty and anemia, conditions that are often not adequately recognized or treated. Recent studies have shown that the prevalence of preoperative anemia in cardiac surgery can exceed 40% and is frequently associated with deficiencies in iron, vitamin B12 and folate [13].

Transfusion requirements represent a clinically relevant outcome in patients undergoing cardiac surgery, as the use of blood components has been associated with an increased risk of infections, organ dysfunction, prolonged hospitalization and higher healthcare costs. Multiple lines of evidence have demonstrated that optimizing nutritional status and treating preoperative anemia can significantly reduce the need for transfusions [14, 15]. In this context, we anticipate that a high proportion of patients enrolled in our study will present with these baseline conditions. Accurate identification and management of preoperative anemia is a crucial component of surgical patient preparation, particularly in cardiac surgery, where the risk of transfusion is high. The recent recommendations from the International Consensus Conference on Anemia Management in Surgical Patients (ICCAMS, 2023) emphasize the importance of early hematologic screening, ideally at least four weeks prior to surgery [16].

In this context, our protocol proposes a multidisciplinary prehabilitation approach that includes early assessment and correction of nutritional deficiencies, with the goal of improving hematologic parameters prior to surgery. This pathway is designed to optimize preoperative hematologic status and may potentially be associated with a lower risk of perioperative anemia and reduced number of red blood cell units transfused. Moreover, patients' nutritional status and dietary habits are well-recognized and modifiable risk factors capable of influencing both the onset and progression of cardiovascular disease, as well as susceptibility to clinical frailty in candidates for cardiac surgery [17]. In this regard, the ERAS guidelines for cardiac surgery recommend implementing nutritional interventions already in the preoperative phase, with the aim of correcting potential deficiencies and improving metabolic management, particularly glycemic control [18].

Cardiac surgery is associated with an intense systemic inflammatory response induced both by surgical trauma and, when applicable, the use of cardiopulmonary bypass. In the presence of preexisting malnutrition, this response may be further amplified, leading to an increased risk of organ dysfunction and poorer clinical outcomes [19]. Furthermore, the inflammatory and regenerative responses triggered by cardiac surgery impose higher nutritional demands, creating a metabolic stress that is further exacerbated by the "standard" preoperative fasting period. Targeted nutritional interventions in the preoperative phase - such as protein supplementation or the use of immunonutritional formulas - may help mitigate this imbalance and support postoperative anabolic adaptation [20].

Among the nutritional strategies applicable in the preoperative phase, particular importance is given to the prolonged consumption of foods rich in antioxidants and the use of specific supplements enriched with omega-3 fatty acids, known for their immunomodulatory properties. These interventions may contribute to improving the patient's nutritional status, with potential benefits in terms of reducing postoperative complications [21].

The use of specific immunonutritional supplements, such as L-arginine and omega-3 fatty acids, initiated in

the preoperative phase, has been associated with a significant reduction in postoperative infectious complications and length of hospital stay, as demonstrated by a recent meta-analysis [22].

In our protocol, personalized nutritional supplementation is initiated in patients with documented deficiencies and its impact will also be evaluated through specific clinical outcomes, such as the incidence of postoperative infectious events.

Following cardiac surgery, a substantial proportion of patients develop pulmonary complications, which are associated with varying degrees of morbidity, mortality and prolonged hospital stay [23]. A randomized controlled trial demonstrated that a structured preoperative Inspiratory Muscle Training (IMT) program, performed for at least two weeks before coronary artery bypass grafting (CABG), significantly reduced postoperative pulmonary complications, including the incidence of pneumonia and shortened hospital length of stay [24].

Although our study does not employ a strict IMT protocol, patients are instructed to perform daily respiratory exercises using the Tri-Flow volumetric incentive spirometer. Our protocol prescribes 5–6 times per day, 3–4 repetitions, ideally for approximately 30 days prior to surgery. This approach still promotes lung expansion and encourages deep, controlled breathing, thereby contributing to the reduction of postoperative respiratory complications [25].

Based on the available evidence, we hypothesize that in our setting, the systematic use of the Tri-Flow device may also contribute to improved respiratory outcomes, including a reduction in the incidence of pneumonia and a shorter hospital stay. Furthermore, the preoperative program includes a recommendation for smoking cessation, which is recognized as an effective measure for improving respiratory outcomes in surgical patients. It has been demonstrated that quitting smoking at least four weeks before surgery is associated with a significant reduction in the risk of pneumonia, atelectasis, postoperative respiratory complications and prolonged hospital stay [26, 27].

Although our clinic is typically activated approximately one month before surgery, some patients are contacted at the earliest stages of the waiting list, allowing for timely counseling on smoking cessation. This early intervention represents a key opportunity: according to the literature, longer periods of abstinence (up to 8 weeks) further enhance the benefits, bringing postoperative risk closer to that of non-smokers [28]. For this reason, the recommendation to quit smoking is provided from the very first patient contact.

The psychological component of prehabilitation focuses on mentally preparing the patient to undergo major surgery. Preoperative anxiety is a common phenomenon in patients on the waiting list for cardiac surgery and has been associated with increased postoperative mortality [29]. Patients awaiting cardiac surgery tend to experience anxiety and depression [30]. Evidence has shown a correlation between psychological factors such as anxiety, depression and stress and poorer surgical outcomes, including increased postoperative pain, delayed functional recovery and higher incidence of complications. It has also been demonstrated that targeted psychological interventions such as preoperative counseling, relaxation techniques, patient education and stress management training can reduce anxiety, perceived pain and improve postoperative outcomes [31, 32].

In our clinic, the use of validated tools such as the Hospital Anxiety and Depression Scale (HADS) allows for the early identification of patients at psychological risk, enabling timely interventions. We also believe that psychological well-being may be associated with greater adherence to the preoperative program, including respiratory exercise and nutritional optimization.

An additional benefit of psychological intervention in the preoperative phase is the ability to support patients who are hesitant or uncertain about undergoing surgery. It has been observed that anxiety and poor understanding of the surgical procedure may lead some patients to postpone or refuse the operation, even when it is clinically indicated [33]. In such cases, psychological support can reduce ambivalence, strengthen the therapeutic alliance and facilitate informed decision-making, thereby contributing to an increase in the number of patients who ultimately undergo surgery.

In addition, interventions aimed at optimizing nutritional status, correcting anemia, improving respiratory function, and reducing preoperative anxiety may contribute to lower rates of postoperative complications, the number of red blood cell units transfused, and the length of hospital stay, which are factors potentially related to healthcare resource use [34]. In this regard, our study may provide preliminary data to inform future assessments of the cost-effectiveness of a multidisciplinary prehabilitation model in cardiac surgery.

Moreover, interest in tele-prehabilitation is steadily increasing in the field of cardiac surgery, due to its potential to deliver a structured and personalized program remotely, thereby improving patient accessibility and adherence. In line with this evidence, our clinic is currently developing a dedicated app designed to guide patients throughout the entire preoperative pathway, with particular focus on those who are frail or face logistical challenges.

In our clinic, the app associated with the *e-poles* med device enables continuous remote monitoring of training parameters and exercise execution technique. The *e-poles* device allow patients to perform exercises with the

advantage of real-time digital monitoring. Equipped with inertial sensors, they transmit data on step symmetry, push angle, cycle frequency and heart rate to a dedicated app and a web portal. The training program primarily consists of low-intensity walking using alternating or parallel technique, along with mobility exercises for upper and lower limbs.

This technology enables remote supervision by the healthcare team, facilitating program personalization, reinforcing adherence and optimizing outcomes even at a distance.

The project also foresees the integration of physical activity data with psychological and nutritional support data into an electronic platform. This platform not only allows centralized data collection but also enables safety alerts, patient-initiated calls for feedback or questions and continuous monitoring of the program by both patients and healthcare professionals.

Supporting this approach, the recent DCC trial demonstrated the effectiveness of tele-prehabilitation in improving clinical outcomes after cardiac surgery, confirming its feasibility and potential benefits in terms of active patient participation and reduced complications [35].

Limitations

This study has several limitations inherent to its observational design and the use of a historical control group. Although the prehabilitation cohort is prospectively enrolled, the retrospective nature of the comparator may introduce residual confounding and limit causal inference. Furthermore, the impossibility of retrospectively applying identical feasibility criteria to the historical cohort may result in selection bias.

Although transfusion practices follow stable institutional protocols, some degree of variability inherent to individualized clinical decision-making cannot be entirely excluded.

Despite these limitations, the study reflects real-world clinical practice and may provide preliminary evidence to inform future randomized investigations.

Conclusions

In conclusion, the present study aims to evaluate the effectiveness of a structured multidisciplinary prehabilitation program in patients undergoing elective cardiac surgery, with particular focus on perioperative clinical outcomes. The systematic implementation of targeted interventions on nutritional status, muscle and respiratory function, and psychological well-being may contribute to improved postoperative outcomes, including transfusion requirements and hospital length of stay.

These potential benefits, in addition to supporting patient recovery and quality of care, may also be associated with improved resource utilization through a possible reduction in complications and prolonged hospitalization. The results of this study may contribute preliminary evidence to inform the future integration of structured prehabilitation models into routine clinical practice and to further research in perioperative medicine, including digitally supported care pathways.

Abbreviations

ERAS	Enhanced recovery after surgery
SPIRIT	Standard protocol items recommendations for interventional trials
CFS	Clinical frailty scale
BMI	Body mass index
MUST	Malnutrition universal screening tool
MNA	Mini nutritional assessment
HADS	Hospital anxiety and depression scale
IMT	Inspiratory muscle training

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13019-026-04110-z.

Supplementary Material 1: The MUST (Malnutrition Universal Screening Tool) scale, employed for the rapid screening of nutritional risk in adults.

Supplementary Material 2: The MNA (Mini Nutritional Assessment) scale, employed to assess the nutritional status of patients aged over 65 years.

Supplementary Material 3: Short Physical Performance Battery (SPPB): assesses functional mobility and strength through balance, gait speed and chair stands.

Supplementary Material 4: User manual of the e-Poles app: a step-by-step guide to using the e-Poles application.

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Not applicable.

Author contributions

GS contributed to the conceptualization of the study, study design, interpretation of results and manuscript writing. As the first author, he also provided overall supervision and critical revision of the manuscript. VD contributed to manuscript writing and study planning, and will contribute to data collection and project management. CP will contribute to data collection and contributed to the editing of the study. MC and GP will focus on the nutritional aspects of the study, including data collection, analysis and development of nutritional plans. MF and SP will contribute to the psychological aspect of the study by administering the HADS test, interpreting results and providing psychological support to patients. NN and LM will be responsible for administering breathing exercises using the Triflow device. EV and LS will facilitate patient recruitment and provide clinical supervision. AF will contribute to data collection and to the retrospective analysis. VC contributed to the preparation of the manuscript. MC will contribute to the management of patients in the outpatient clinic. SA contributed to the statistical aspects of the protocol. RB will contribute to data collection. GS guided the study design and methodology, supervised all aspects of data collection and analysis and critically revised the manuscript. All authors read and approved the final version of the manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study has been approved by the Ethics Committee of Bari, Italy. Written informed consent will be obtained from all participants prior to enrollment.

Consent for publication
Not applicable.

Competing interests
Supplements intended to address potential deficiencies were provided by Essecore.

Author details
[1]Department of Clinical and Experimental Medicine, Magna Graecia University, Viale Europa, Catanzaro 88100, Italy
[2]Department of Cardiac Surgery, Città di Lecce Hospital, GVM Care & Research, Lecce, Italy
[3]Paracelsus Medical University, Nuremberg, Germany
[4]Department of Clinical Nutrition, Città di Lecce Hospital, GVM Care & Research, Lecce, Italy
[5]Department of Biosciences, Biotechnology and Environment, University of Bari Aldo Moro, Bari, Italy
[6]Department of Hospital Psychology, Città di Lecce Hospital, GVM Care & Research, Lecce, Italy
[7]Department of Cardiology, Bassini Hospital, Milano, Italy
[8]Personal Management Department, Città di Lecce Hospital, GVM Care & Research, Lecce, Italy
[9]Department of Human and Social Sciences, University of Salento, Lecce, Italy
[10]Department of Cardiac Surgery, Campus Bio-Medico University of Rome, Rome, Italy
[11]Department of Cardiac Surgery, Santa Maria Hospital, GVM Care & Research, Bari, Italy

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