Původní sdělení | Original research article

Impact of invasively determined cardiac power index on survival in patients with advanced chronic heart failure

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SOUHRN

Kontext: Pro stratifikaci rizika pacientů se srdečním selháním se začaly používat hemodynamické parametry. Srdeční výkon (cardiac power output, CPO) je ukazatelem výkonnosti srdce. Index srdeční síly (cardiac power index, CPI) vyjadřuje vztah srdečního výkonu a plochy tělesného povrchu. Cílem studie bylo prokázat prognostickou úlohu klidového CPI u pacientů s pokročilým chronickým srdečním selháním.
Metody: Do studie byli zařazeni pacienti v pokročilém stadiu chronického srdečního selhání, s ejekční frakcí levé komory < 30 % a ve funkčních třídách III a IV, u nichž byla provedena katetrizace pravostranných i levostranných srdečních oddílů. Vyšetřeno bylo celkem 99 pacientů; jedinci, jimž byla implantována centrifugální pumpa k podpoře funkce levé komory (left ventricular assist device, LVAD) nebo u nichž byla provedena transplantace srdce (heart transplantation, HTx), byli ze studie vyloučeni, aby bylo možno stanovit délku přežití bez LVAD a HTx.
Výsledky: Z 99 vyšetřených pacientů byl chirurgický výkon v souvislosti s LVAD nebo HTx proveden u 43 pacientů. Ze zbývajících 56 pacientů jich během sledování s mediánem délky 16 měsíců zemřelo 19 (33,9 %). Hodnota CPI byla spojena s úmrtím ze srdečních příčin (0,32 vs. 0,42, $p = 0{,}003$). Mezní hodnota CPI z hlediska mortality byla 0,41 (senzitivita 89,5 % a specificita 56,8 %). Snížená hodnota CPI (< 0,41 W/m^2) byla rovněž spojena s vysokým tlakem v pravé síni ($p = 0{,}016$) a s plicní cévní rezistencí ($p = 0{,}012$). Kaplanova–Meierova analýza přežití prokázala, že dlouhodobé přežití je statisticky významně kratší u pacientů s CPI < 0,41.
Závěr: Klidový CPI je u pacientů s pokročilým chronickým srdečním selháním spojen s úmrtím ze srdečních příčin.

ABSTRACT

Background: Hemodynamic parameters have recently emerged as tools for risk stratification of heart failure patients. Cardiac power output (CPO) is an indicator of cardiac performance. Cardiac power index (CPI) is calculated by indexing CPO to body surface area. The study aimed to demonstrate the prognostic role of resting CPI in advanced chronic heart failure patients.
Methods: The study included patients with advanced chronic heart failure, ejection fraction below 30%, and classes III and IV functional capacity who had had right and left heart catheterization. A total of 99 patients were enrolled, with those having left ventricular assist device (LVAD) implantation or heart transplantation (HTx) excluded to determine LVAD- and HTx-free survival.
Results: Of the 99 patients, 43 patients underwent LVAD and HTx surgery. Of the remaining 56 patients, 19 died (33.9%) over a period of 16 months (median). The value of CPI was associated with cardiac mortality (0.32 vs 0.42, $p = 0.003$). The cut-off level of CPI for mortality was 0.41 (89.5% sensitivity and 56.8% specificity). A diminished CPI (<0.41 W/m^2) was also associated with high right atrial pressure ($p = 0.016$) and pulmonary vascular resistance ($p = 0.012$). A Kaplan–Meier survival analysis indicated that long-term survival was significantly reduced in patients with CPI <0.41.
Conclusion: Cardiac power index at rest is associated with cardiac mortality in patients with advanced chronic heart failure.

Keywords:
Advanced chronic heart failure
Cardiac mortality
Cardiac power index
Prognosis

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Introduction

The heart can be considered a muscular hydraulic pump that can create both flow and pressure.[1] Cardiac output (CO) is the cardiovascular flow through blood vessels and reflects not just cardiac contractility, but, also, vascular compliance, intravascular volume and cardiac filling pressures. The hydraulic function of the heart is identified by cardiac power. The ability of cardiac pumping can be represented by cardiac power output (CPO). CPO is the product of mean arterial pressure (MAP) and CO.[2] Resting CPO is found to be associated with mortality in acute heart failure (HF), especially in cardiogenic shock.[3] Cardiac power index (CPI) is CPO indexed to body surface area (BSA). The term advanced chronic HF refers to the progressive deterioration of HF symptoms with a reduced ejection fraction and biochemical and clinical signs of heart failure.[4] The current study aimed to investigate the effect of resting cardiac power index on the survival of advanced chronic HF patients.

Methods

Included in our study were 99 patients undergoing right and left heart catheterization due to advanced chronic HF between January 2017 and March 2020. The 99 patients were evaluated by a heart team consisting of a cardiologist and cardiovascular surgeons. Of this number, 43 patients who had left ventricular assist device (LVAD) implantation and heart transplantation (HTx) were excluded from the study. The remaining group included 56 patients with advanced chronic HF. All patients had left ventricular ejection fraction (LVEF) <30% and were classes III and IV functional capacity. The patients were followed from catheterization to June 2020. Follow-up duration was defined as the period from catheterization to either cardiac death or June 2020 (in survivors). Informed consent was obtained from all patients and the study protocol was approved by the Institutional Review Board.

Hemodynamic measurements were performed via the femoral artery and vein. Mean arterial pressure was measured using a catheter placed in the ascending aorta. Another catheter was advanced into the pulmonary artery until wedge position to measure pulmonary capillary wedge pressure (PCWP). Pulmonary artery pressure and right atrial pressure (RAP) were also determined. Cardiac output was calculated using Fick's equation.

Cardiac power output [W] was calculated as follows: CPO = CO × mean arterial pressure × K (K = 0.0022, conversion factor). Cardiac power index (CPI) was calculated by dividing CPO by body surface area (BSA). CPI [W/m^2] = CPO [W] / (BSA [m^2]).

Statistical analysis

Statistical analyses were performed using SPSS software (version 22.0; SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was performed to assess normality of distribution. Continuous variables were indicated as mean±standard deviation (SD) or median (25–75 percentiles). An independent t test was used for parametric assumptions. The Mann–Whitney U test was used for non-parametric assumptions. Frequencies and percentages were defined for categorical data. Comparisons of categorical variables were conducted using the Pearson chi square or Fisher's exact test.

A receiver operating characteristic (ROC) curve was generated for discriminative ability of CPI to predict mortality in advanced patients with chronic HF. Results were presented as the area under the curve (AUC) and 95% confidence intervals (CI). A cut-off level of CPI was determined with sensitivity and specificity. A Kaplan–Meier survival analysis was also performed to demonstrate the effect of CPI according to the determined cut-off level. A *p*-value less than 0.05 was accepted to indicate statistical significance.

Results

Of the 56 patients, 19 patients died (33.9%) over a period of 16 months (median). CPI was associated with cardiac mortality (0.32 [0.26–0.38] vs 0.42 [0.31 vs 0.52], p = 0.003). In terms of ROC analysis, the cut-off level of CPI for mortality was 0.41 (89.5% sensitivity and 56.8% specificity; AUC = 0.745, p = 0.003; 95% CI [0.616–0.875]) (Fig. 1). According to this cut-off level, the study group was stratified into two groups. No significant difference was found in baseline clinical and laboratory features (Table 1). Of the catheterization findings, reduced CPI (<0.41W/m^2) was also related with high right atrial pressure (p = 0.016) and pulmonary vascular resistance (p = 0.012), apart from cardiac output and index (Table 2). A Kaplan–Meier survival analysis indicated that long-term survival was significantly reduced in patients with CPI <0.41 (log rank p = 0.003) (Fig. 2).

Reduced CPI (<0.41W/m^2) was also found to be associated with high right atrial pressure (RAP) and pulmonary vascular resistance other than cardiac output and index in our study. As expected, these markers might be related in advanced heart failure patients.

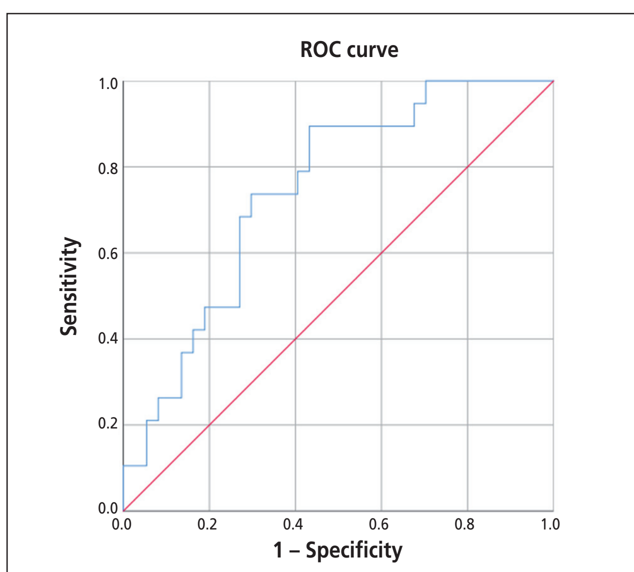

Fig. 1 – ROC analysis of CPI and cardiac mortality.

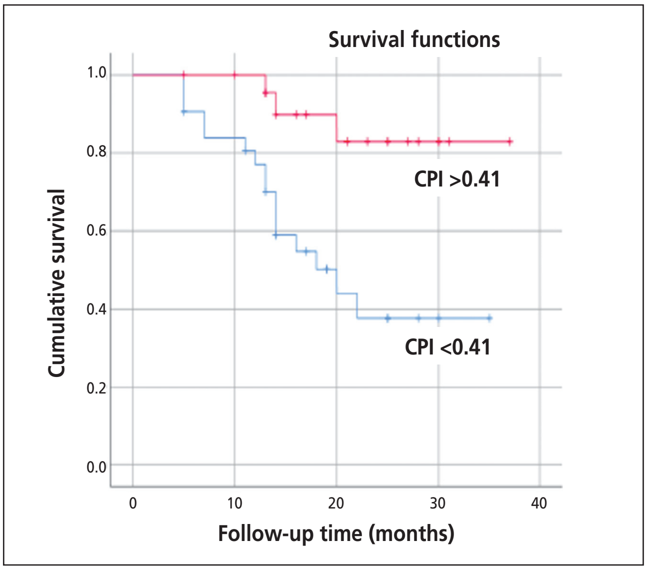

Fig. 2 – Kaplan–Meier survival curves for low and high CPI (according to cut-off level of 0.41).

Discussion

This study demonstrated that resting CPI was significantly related to cardiac mortality. CPI was associated with LVAD- and HTx-free survival.

A sub-analysis of the SHOCK study by Fincke et al shows that CPO has the strongest hemodynamic correlation as a result of cardiogenic shock.[3] This hemodynamic parameter is gaining importance as a measure of cardiac pumping ability. Resting CPO, maximal CPO, and reserve CPO (maximal CPO – resting CPO) are power outputs of the heart. As a result of pump malfunction, the maximal CPO falls with matching decreases in reserve CPO; and, if severe, this is followed by decreases in resting CPO.[5] Lang et al demonstrated that noninvasively recorded maximal CPO is an independent predictor of outcome.[6] The impact of resting CPO on prognosis in chronic HF was evaluated by Yildiz et al who concluded it was an independent predictor of adverse outcomes. They enrolled 161 patients and indicated that resting CPO below <0.54 W was associated with worse outcomes.[2] Another study, by Grodin et al, evaluated resting CPI with 495 ambulatory patients with advanced HF who had invasive hemodynamic testing and were followed up for unfavorable outcomes (all-cause mortality, HTx, or left ventricular assist device implantation). CPI was 0.44 W/m^2 (interquartile range 0.37, 0.52), there were 117 deaths, 104 HTx and 20 LVAD implantation procedures over a median of 3.3 years.[1] In our study with 99 patients, 19 patients died, 43 patients underwent LVAD implantation or HTx procedures over a period of 16 months. The cut-off CPI value for mortality was 0.41 W/m^2 with 89.5% sensitivity and 56.8% specificity.

A diminished resting CPI was linked to frequent indicators of advanced heart failure.[7] In our study, higher values of PVR and RAP were found to be associated with CPI below 0.41 W/m^2. It is not unexpected that these parameters are increased secondary to heart failure.

Our study group included patients with LVEF <30% and classes III and IV functional capacity. Morimoto et al showed that, in patients with non-ischemic dilated cardiomyopathy, less severe systolic dysfunction (EF <45%) and a functional class II or III, CPI is also effective in predicting cardiac events. Yet, this prognostic value depends on the mean arterial pressure.[8]

We evaluated patients with systolic heart failure. However, a recently published article by Harada et al investigated HF with preserved ejection fraction. In the study, the primary end point was defined as cardiovascular death and hospitalization for heart failure. It was concluded that other measures of heart performance were not linked to negative outcomes, although CPO was.[9]

Resting CPO and CPI were primarily focused on left ventricular function. A recent study investigated right ventricular CPO in advanced HF patients. The authors concluded that a higher resting RV CPO was an independent predictor of adverse clinical endpoints.[10]

Our study has the following limitations: First, it was a single-center, retrospective study and, as a result, it was prone to bias. The study enrolled a relatively modest number of patients. There was no serial measurement of CPI; it was only done once; hence, changes in CPI values were not considered. Another interesting point is the definition of CPO. It was stated in an article that CPO should be calculated as CO × (MAP – RAP) × K (K = 0.0022). The author emphasized the importance of RAP and suggested that future studies should include RAP in the calculation of CPO.[11] Moreover, B-type natriuretic peptide (BNP) level was not measured in our study. Lastly, donor availability and LVAD selection criteria may have caused bias due to the fact that the study aimed to show LVAD- and HTx-free survival.

Conclusion

Resting cardiac power index is related to cardiac mortality in patients with advanced chronic heart failure. A CPI below the 0.41 level is associated with worse survival rates. CPI is a reliable prognostic indicator and should be used for risk stratification in advanced heart failure patients.

Conflicts of interest

None.

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None.

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