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Cost-effectiveness analysis of nurse practitioner-led care for patients with heart failure in Japan

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Research Article

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Abstract

Background

Heart failure (HF) is a leading cause of hospitalization and mortality in Japan. As its population ages rapidly, Japan is projected to experience an “HF pandemic” by 2030, placing an unprecedented burden on health care systems. Owing to increasing physician shortages and regional disparities in access to care, nurse practitioner (NP)-led care has been proposed as a promising strategy for sustainable HF management. However, no cost-effectiveness analysis of NP-led care for patients with HF has been conducted in Japan.

Methods

We developed a monthly cycle microsimulation Markov model over a 10-year horizon to compare NP-led care plus usual care versus usual care alone for hospitalized patients with HF in Japan (mean age: 76.5 years) from a health care payer perspective. The primary outcome was the incremental cost-effectiveness ratio (ICER) per quality-adjusted life year (QALY) gained, with a willingness-to-pay (WTP) threshold of JPY 5,000,000. A 2% annual discount rate was applied to both costs and outcomes. Deterministic and probabilistic sensitivity analyses were performed.

Results

NP-led care yielded 3.54 QALYs versus 3.19 for usual care at costs of JPY 2,836,905 versus JPY 2,737,740, respectively. The base-case ICER was JPY 278,680 per QALY, which was below the WTP threshold. Under a conservative scenario in which the effect of NP-led care on readmission was reduced by 50%, the ICER was JPY 676,239 per QALY.

Conclusion

NP-led care for patients with HF was cost-effective across a range of sensitivity analyses, supporting its potential as a cost-effective strategy to support HF management in Japan.

Background

Heart failure (HF) is a disease affecting approximately 64 million people worldwide [1] and is an international health challenge accompanied by a high mortality rate, reduced quality of life (QOL), and increased health care costs [2]. As a professional concept initiated in the United States in 1965 based on a public health model to provide primary health care to children lacking access to healthcare services, nurse practitioners (NPs) have since spread internationally and have helped increase health care access in vulnerable areas and manage chronic disease as their role has expanded from primary to acute care

[3]. In the superaging society of Japan, approximately 31.6% of people aged 65 and above are estimated to develop HF by 2030 [4], raising concerns about the associated impact on the health care delivery system during what is being described as a possible “HF pandemic” [5]. Since approximately 27–29% of heart failure (HF) patients are readmitted within one year, HF has a high readmission rate and a high health care cost burden [6]. In Japan, HF hospitalization costs account for 44% of acute cardiovascular disease, totaling $1.187 billion annually, with a median cost per patient of $8,089 per episode [7]. Maintaining the functional abilities of patients with HF requires continuous support from a multidisciplinary team, including physical therapists, nurses, dietitians, and social workers [5]. Moreover, the number of doctors in Japan is below the OECD average [8], with serious regional disparities [9]. Promoting task shifting and sharing through reforms to doctors’ working styles is an urgent policy issue [10]. Although results, such as a reduction in complications from peripherally inserted central catheter (PICC) line insertion [11] and a decrease in emergency room visits [12] have been reported, Japanese NPs are privately certified [13], only 1,118 NPs have been certified as of 2026 [14], and the lack of a national certification system as well as an inadequate compensation system are considered factors hindering the widespread adoption of NPs [15]. Internationally, in a cost-effectiveness analysis (CEA) based on a retrospective cohort, Driscoll et al. reported that, compared with usual care, inpatient care delivered by NPs specialized in HF decreased costs and increased quality-adjusted life years (QALYs) by 12 months and 3 years (approximately AUD 109,000 [Australian dollars] saved per QALY at 12 months and approximately AUD 271,000 saved per QALY at 3 years) and was 100% cost-effective at a willingness-to-pay (WTP) threshold of AUD 50,000 per QALY [16]. However, no CEA has been conducted for NPs, especially in the context of HF, for which the medical cost burden is high in Japan. This study aims to evaluate the cost-effectiveness of NP-led care in addition to usual care compared with that of usual care alone for patients with HF.

Methods

Model overview

We conducted a CEA in which NP-led care was added to usual care for the management of patients hospitalized with HF. The model structure and key parameters were taken from Driscoll et al. [16, 17], with minor adaptations to reflect the Japanese setting. The target population consisted of individuals admitted to the hospital for HF, and the analysis was conducted from the perspective of health care payers. We developed a population-based microsimulation model with a 1-month cycle length and a 10-year time horizon, reflecting the life expectancy of hospitalized patients with HF (mean age 76.5 years at model entry). The state-transition structure began with a hospitalized patient with HF and included in-hospital death or discharge to home. Among those discharged, subsequent health states included living at home, HF readmission, and death (Fig. 1). All data were obtained from published studies and governmental sources (Table 1. For details, see Additional file 1[33, 34, 35]).

Table 1 Input parameters in the base-case and sensitivity analyses

		Range			
Items	Base-case	Lower	Upper	Distribution	Source
Cost/month (JPY)					
NP service fee	1,500	750	2,250	Gamma	Suzuki et al. [15], NHO [18], JROAD [21], Hasebe et al. [23]
Cost for HHF	795,628	612,731	1,002,048	Gamma	Ogawa et al. [24]
Cost for Outpatient HF	15,391	11,853	19,384	Gamma	Eguchi et al. [25]
Probability/month					
NP-led care					
HF readmission rate	0.023	0.018	0.030	Beta	Ide et al. [20], Driscoll et al. [17]
HF in-hospital mortality	0.038	0.030	0.048	Beta	Ide et al. [20], Driscoll et al. [16]
Mortality after discharge from HHF	0.021	0.016	0.026	Beta	Ide et al. [20]
HHF to discharge	0.750	Fixed	Fixed	Beta	Ide et al. [20]
Usual care					
HF readmission rate	0.030	0.023	0.038	Beta	Ide et al. [20]
HF in-hospital mortality	0.077	0.059	0.097	Beta	Ide et al. [20]
Mortality after discharge from HHF	0.021	0.016	0.026	Beta	Ide et al. [20]
HHF to discharge	0.750	Fixed	Fixed	Beta	Ide et al. [20]
Utility					
Utility of initial HF	0.884	0.593	0.998	Beta	Noda et al. [26]
Utility of severe HF	0.768	0.556	0.925	Beta	Noda et al. [26]

Abbreviations: NP, nurse practitioner; HHF, hospitalization for heart failure; HF, heart failure.

Model population

The simulated cohort was based on baseline characteristics from the study by Driscoll et al. [17], which included 408 patients hospitalized with acute HF (222 under NP-led care for HF; 186 under usual care). The mean age was 76.5 ± 12.0 years, and 56.4% of the patients were male. The comorbidities included

ischemic heart disease (54.4%), diabetes mellitus (46.8%), atrial fibrillation (54.4%), renal disease (53.4%), hypertension (76.0%), and hypercholesterolemia (60.8%). At admission, 56.3% of the patients were prescribed beta-adrenergic blockers, 59.6% were prescribed angiotensin-converting enzyme inhibitors/angiotensin II receptor blockers (ACEIs/ARBs), and 25.0% were prescribed mineralocorticoid-receptor antagonists (MRAs). The median length of the hospital stays ranged from 6–7 days, and the median Charlson Comorbidity Index was 5.8 ± 3.3 (range 5.2–6.3 depending on group allocation).

Intervention strategies

This intervention was based on the model of care reported by Driscoll et al. [17] HF treatment with NP-led care added to usual care was compared to usual care alone. Usual care consisted of standard inpatient management and routine postdischarge outpatient follow up, without the involvement of an HF specialist nurse during hospitalization. NP-led care added a structured, multicomponent program delivered and coordinated by NPs during the inpatient stay, in addition to usual care. Interventions were based on Australian and international HF guideline recommendations and included advanced clinical assessment, medication review, optimization of evidence-based pharmacotherapy (beta-blockers, ACEIs, MRAs, or ARBs), interpretation of diagnostic tests, and referral to multidisciplinary community services. NPs provided repeated visits according to the severity of the patient's condition, HF knowledge, and self-management needs and offered tailored education for patients and caregivers. Discharge planning incorporated referrals to underutilized community resources, including early outpatient review by HF specialists within 7–10 days and home-based HF support programs.

Model inputs

Cost

The monthly NP allowance (JPY 60,000) was used as the total cost [15, 18]and was divided by the total number of patients seen per month across both inpatient and outpatient settings [19–21]in accordance with the Global Health Cost Consortium (GHCC) Reference Case guidelines [22]. Subsequently, inpatient and outpatient NP unit costs were estimated separately to enable setting-specific cost-effectiveness analyses [23]. Hospitalization costs for HF were based on estimates reported by Ogawa et al. [24] and were calculated as the sum of bundled and fee-for-service payments. Outpatient HF costs were taken from Japanese data reported by Eguchi et al., who used Diagnosis Procedure Combination (DPC) claims for 42,830 patients to extract HF-related outpatient expenditures, aggregate them per individual, and calculate annual per-patient costs [25].

Transition probabilities

Because no studies in Japan have evaluated the effectiveness of NP-led care for HF, we used the 30-day HF readmission rate from the nationwide, multicenter JROADHF registry as the reference baseline and applied it as the monthly transition probability [20]. The NP effect was then estimated by multiplying this monthly probability by the relative risk (RR) derived from the 12-month cumulative readmission rates

reported by Driscoll et al. [17], yielding the monthly readmission probability for the NP arm. Since no Japanese studies have examined the effect of NP intervention on in-hospital mortality from HF, we used the in-hospital mortality rate for HF from real-world data in Japan, as reported by Ide et al. [20], as the control group value. To determine the effect of NP, we applied the RR derived from Driscoll et al. to the Japanese baseline in-hospital mortality and used this value for the intervention group. For the mortality rate after discharge from HF, we used the pure all-cause mortality rate for HF, rather than the NP intervention, from Ide et al.'s real-world data from Japan [20], and applied the same value to both groups. The discharge rate after HF was not based on any NP-related effect but on real-world data from Japan representing the natural course of HF care. Specifically, Ide et al. reported a 75th-percentile length of stay of 28 days, from which a provisional 30-day discharge probability of 0.8 was derived and applied equally to both groups [20].

Utility

Utility values for mild (NYHA II) and severe (NYHA III/IV) HF were adopted from Noda et al. [26] In our model, these were applied to the postdischarge and in-hospital states.

Analytical methods

CEA

This analysis simulated a cohort of 100,000 individuals. The model used a 1-month cycle length and a 10-year time horizon for the base-case analysis. Health outcomes were expressed in QALYs, and the incremental cost-effectiveness ratio (ICER) was calculated as incremental costs divided by incremental QALYs. Both costs and QALYs were discounted at an annual rate of 2%, as recommended in the Japanese cost-effectiveness guidelines [27]. A WTP threshold of 5 million yen per QALY, as recommended in the national policy document, was applied [28]. Population-based Monte Carlo simulations were performed using TreeAge Pro Healthcare 2026 (TreeAge Software, Inc.).

Sensitivity analysis

A one-way sensitivity analysis was conducted to assess the influence of individual parameters on the model results. The net monetary benefit (NMB) was used as the summary measure, with gains in QALYs converted into monetary values using a WTP threshold of 5 million yen per QALY. To evaluate the impact of joint uncertainty across all model inputs, a probabilistic sensitivity analysis (PSA) was performed with approximately 5,000 iterations. Gamma distributions were applied to the cost parameters, and beta distributions were applied to the transition probability and utility parameters. The NP service cost was represented by a standard deviation (SD) set at ±50% of the base-case value to consider uncertainty; for all other parameters, an SD of ±12.5% of the base-case value was used. The corresponding distribution parameters were then derived from these SDs.

Scenario analysis

The risk ratios for NP interventions were obtained from Australian studies [16, 17], where NPs are legally granted prescriptive authority and a broader scope of practice than they are in Japan, where NPs do not hold independent prescriptive authority. To account for the potential overestimation of effect sizes attributable to this difference in the scope of practice, a scenario analysis was performed in which the risk ratios for the readmission rates were attenuated by 50%.

Threshold analysis

We performed a threshold analysis for the NP service costs in both outpatient and inpatient settings to identify cost-effective scenarios using a WTP threshold of JPY 5,000,000 per QALY.

Ethics statement

This simulation relied exclusively on previously published data and did not involve any new research with human participants or animals; therefore, ethical approval was not required.

Results

Base-case analysis

In this model-based economic evaluation, a cohort of 100,000 individuals was simulated to assess the cost-effectiveness of HF management with NP-led care. Over the 10-year time horizon, HF treatment in the NP-led care group yielded 3.54 QALYs per person, compared with 3.19 QALYs in the usual care group. The average HF treatment cost per person over 10 years—including medication, hospitalization, and outpatient services—was higher in the NP-led care group than it was in the usual care group (JPY 2,836,905 vs. JPY 2,737,740). Under a WTP of 5,000,000 yen per QALY, HF treatment with NP-led care was more cost-effective than usual care, with an ICER of 278,680 yen/QALY (Table 2).

Table 2 Summary of the base-case cost-effectiveness analysis

Indicators	NP-led care	Usual care	Incremental
Cost (JPY)	2,836,905	2,737,740	99,165
QALY	3.54	3.19	0.35
ICER (JPY/QALY)			278,680

Note: A 2% annual discount rate was applied to both costs and outcomes, implemented on a monthly basis to match the 1-month cycle length, over a 10-year time horizon.

Sensitivity analysis

Figure 2 presents the tornado diagram of the top 9 variables in the one-way sensitivity analysis of the ICER. The HF rehospitalization rates in both the usual care group and the NP-led care group had the

greatest influence on the ICER, followed by all-cause mortality during hospitalization for HF in the usual care group. Notably, even the parameter with the greatest impact on the ICER remained below JPY 5,000,000 per QALY, indicating that NP-led care was cost-effective across all parameter ranges examined.

The ICER scatter plot for the HF patient population revealed that NP-led care was superior in 29.3% of the replicates and cost-effective in terms of 100% of the replicates, with an ICER below the threshold of JPY 5,000,000 per QALY (Fig. 3).

The CEA curve (CEAC) reveals that the probability of NP-led care being cost-effective increased sharply as the WTP thresholds increased, reaching approximately 100% at the conventional Japanese threshold of JPY 5,000,000 per QALY gained (Fig. 4). These results were consistent with the ICE scatterplot findings and further supported the cost-effectiveness of NP-led care compared with usual care across a wide range of WTP thresholds.

Scenario analyses

Scenario analyses revealed that when the effectiveness of NP-led care was halved, the ICERs were JPY 676,239 per QALY for the readmission rate (Table 3). At a WTP threshold of JPY 5,000,000 per QALY, the ICERs remain below it, indicating cost-effectiveness in these scenarios (Table 4).

Table 3 Scenario analysis: NP effectiveness (RR) halved for readmission reduction

Indicators	NP-led care	Usual care	Incremental
Cost (JPY)	2,964,775	2,738,032	226,743
QALY	3.52	3.19	0.33
ICER (JPY/QALY)			676,239

Abbreviations: JPY, Japanese yen; QALY, quality-adjusted life years; ICER, incremental cost-effectiveness ratio; NP, nurse practitioner; RR, relative risk.

Table 4 Threshold analysis of NP service fee per patient per month for cost- effectiveness in inpatient and outpatient settings

Parameter	Baseline (JPY/month)	Baseline ICER (JPY/QALY)	Threshold (JPY/month)
NP service fee: Inpatient	1,500	278,666	650,261
NP service fee: Outpatient	1,500	278,613	38,133

Abbreviations: JPY, Japanese yen; ICER, incremental cost-effectiveness ratio; QALY, quality-adjusted life years; NP, nurse practitioner.

Threshold analysis

The cost-effectiveness thresholds for outpatient and inpatient expenses were JPY 38,133 and JPY 650,261, respectively.

Discussion

This study provides evidence on the cost-effectiveness of combining NP-led care with usual care in patients with HF. Our microsimulation analysis revealed that NP-led care not only enhances clinical outcomes but also represents a cost-effective intervention across the entire study population, based on a WTP threshold of JPY 5,000,000 per QALY. Sensitivity analyses confirmed the robustness of these findings, suggesting that NP-led care was associated with enhanced health outcomes and appeared to be a cost-effective intervention in the simulated population. Our findings are consistent with those of previous studies on health economic evaluations in HF care [16, 29]. A systematic review of randomized controlled trials (RCTs) examining the effectiveness and costs of NP-led care in outpatient primary care settings suggested that NP-led care achieved outcomes equivalent to or better than those of physicians, and could decrease costs [30]. The present study further supports these findings from an economic perspective. Our threshold analysis revealed that NP-led care costs could increase total costs by up to JPY 38,133 per patient per month, approximately 25 times the baseline assumption of JPY 1,500, while remaining cost-effective at a WTP threshold of JPY 5,000,000 per QALY, providing economic justification for the broader implementation of NP-led care in outpatient settings in Japan. A systematic review investigating NP roles in inpatient settings, which included predominantly neonatal populations, reported that NPs were as effective as physicians, with equivalent or lower resource use, although the quality of the economic evidence was rated as poor [31]. The present threshold analysis for inpatient NP-led care costs yielded a threshold of JPY 650,261 per patient per month, approximately 434 times the baseline assumption of JPY 1,500, at a WTP threshold of JPY 5,000,000 per QALY. This exceptionally wide margin may reflect the relatively small contribution of NP-led care costs to total inpatient costs rather than superior NP effectiveness per se and may indicate that the cost-effectiveness is robust. Nevertheless, these findings suggest that even if NP roles were formally institutionalized in Japan and associated service costs increased substantially, cost-effectiveness is unlikely to be compromised, underscoring the economic feasibility of such a policy direction. Given the limited and dated nature of existing evidence, particularly its focus on neonatal care, the present study helps to fill a critical gap in the economic evaluation of NP roles in adult inpatient settings.

To our knowledge, this study represents the first CEA of NPs conducted in Japan, providing novel economic evidence in a context in which the NP role remains institutionally nascent. Furthermore, to address the potential risk of overestimation from applying effect sizes derived from studies on NPs in Australia, where NPs hold prescribing authority unlike their Japanese counterparts, we conducted a scenario analysis in which the effect size of the NP intervention on readmission was conservatively halved. Notably, NP-led care remained cost-effective even under this conservative assumption, supporting the robustness of our findings.

Implications for practice

The cost-effectiveness demonstrated in this study has important implications for addressing the structural barriers to implementation of NP-led care in Japan. Currently, Japanese NPs operate under a private certification system without national licensure, and the lack of formal reimbursement mechanisms is a major obstacle to widespread adoption [15]. The International Council of Nurses (ICN) guidelines emphasize that the credibility and sustainability of NP practice are underpinned by a clearly defined scope of practice; advanced educational preparation; and legal authority, including prescriptive rights [3]. Notably, prescriptive authority is identified as a central element for maximizing NP practice, and this authority should be managed through national regulatory frameworks [3]. Furthermore, the ICN positions title protection and the establishment of credentialing systems as essential requirements, as these mechanisms serve to protect the public from unqualified practitioners and ensure the trustworthiness of the NP profession [3]. One reason that NP intervention maintained cost-effectiveness in this study is that our scenario analysis, which conservatively halved the effectiveness of the NP decrease in readmission rates to address the risk of overestimation inherent in applying effect estimates from Australian NPs with prescriptive authority [32], demonstrated that cost-effectiveness was sustained even under this conservative assumption. This finding implies that if Japanese NPs were to acquire prescriptive authority and greater clinical autonomy, substantially greater clinical and economic benefits could be anticipated. Moreover, the threshold analysis revealed that NP-led care costs could increase up to 25-fold in outpatient settings and over 434-fold in inpatient settings while maintaining cost-effectiveness at the WTP threshold. These findings indicate the substantial economic feasibility of integrating appropriate reimbursement mechanisms within Japan's national health insurance system and establishing NPs as nationally credentialed professionals. Drawing on international experience with NP implementation, our findings may support discussions regarding the future regulatory development of NP-led care in Japan.

Limitations

This study has several limitations. First, the effect size for NP interventions was applied as a risk ratio derived from Australian studies to the Japanese HF distribution; because Australian NPs have prescribing authority [32] whereas Japanese NPs do not, this approach may overestimate the true effect. If real-world Japanese data become available, simulations that are more detailed and that are tailored to regional population demographics could be performed and would likely have substantial implications for Japanese health care policy. Second, the studies used to inform the input parameters were observational rather than RCTs, which introduced a risk of bias. Third, the simulation modeled only inpatient and outpatient settings and did not include home-based care such as palliative services. Fourth, the model did not account for potential heterogeneity in NP competency or institutional capacity, which may vary substantially across hospitals and regions in Japan.

Conclusions

This study provides the first CEA of NP-led care for patients with HF in Japan. NP-led care was found to be cost-effective at Japan's conventional WTP threshold of JPY 5,000,000 per QALY, with an ICER of JPY 278,680 per QALY over a 10-year time horizon. Sensitivity analyses confirmed the robustness of these findings. These results suggest that NP-led care warrants consideration in HF management policy in Japan.

Abbreviations

ACEI
angiotensin-converting enzyme inhibitor
ARB
angiotensin receptor blocker
CEAC
cost-effectiveness acceptability curve
CEA
cost-effectiveness analysis
DPC
diagnosis procedure combination
GHCC
Global Health Cost Consortium
HF
heart failure
ICER
incremental cost-effectiveness ratio
ICN
International Council of Nurses
MRA
mineralocorticoid-receptor antagonist
NMB
net monetary benefit
NP
nurse practitioner
NYHA
New York Heart Association
OECD
Organisation for Economic Co-operation and Development
PICC
peripherally inserted central catheter
PSA
probabilistic sensitivity analysis

QALY
quality-adjusted life year
QOL
quality of life
RR
relative risk
SD
standard deviation
WTP
willingness-to-pay

Declarations

Ethics approval and consent to participate

Not applicable since this article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

Consent for publication

Not applicable.

Availability of data materials

The dataset supporting the conclusions of this paper is provided in Supplementary Material 1.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

KU contributed to the conception of the study. KU, SO, and SS contributed to the study design. KU, ES, SS, and SO contributed to data acquisition. KU, SO, and SS contributed to the analysis and interpretation of the data. KU drafted the manuscript. KU, ES, SS, and SO contributed to revising the manuscript and have read and approved the final manuscript.

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Figures

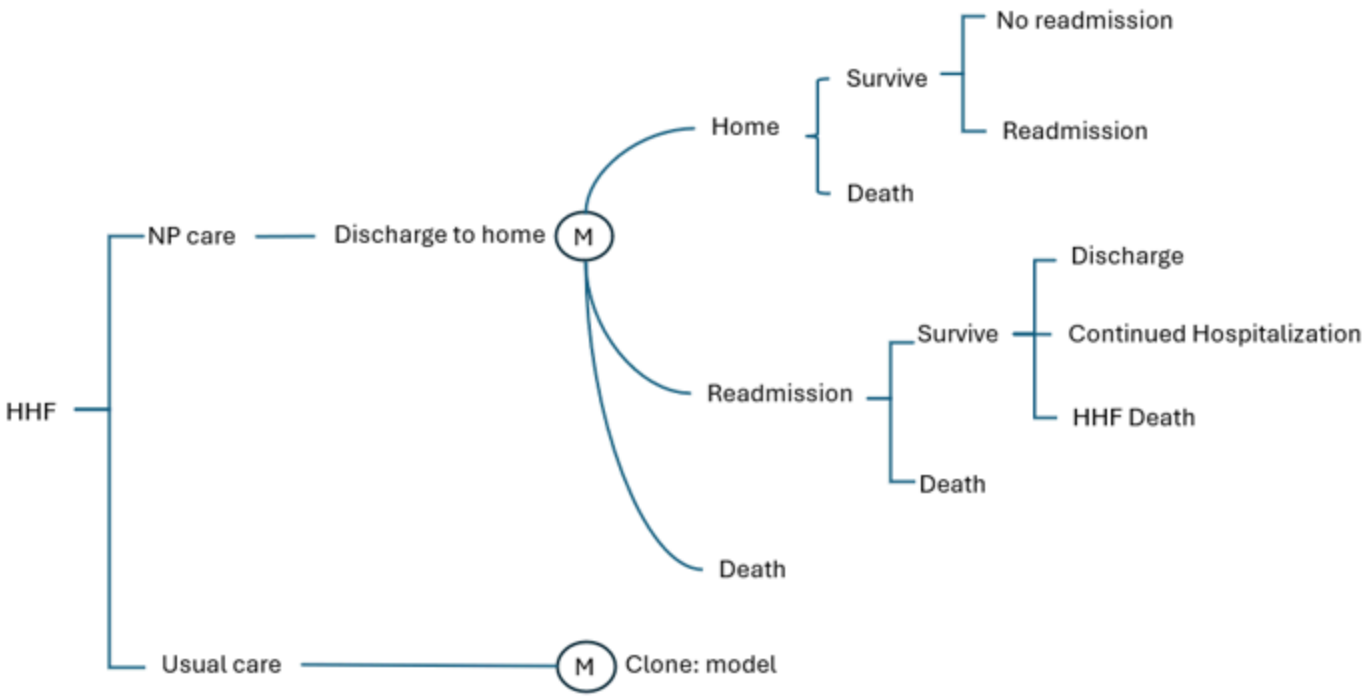


Figure 1

Schematic diagram of the decision tree structures in the state transition model of NP-led strategies.

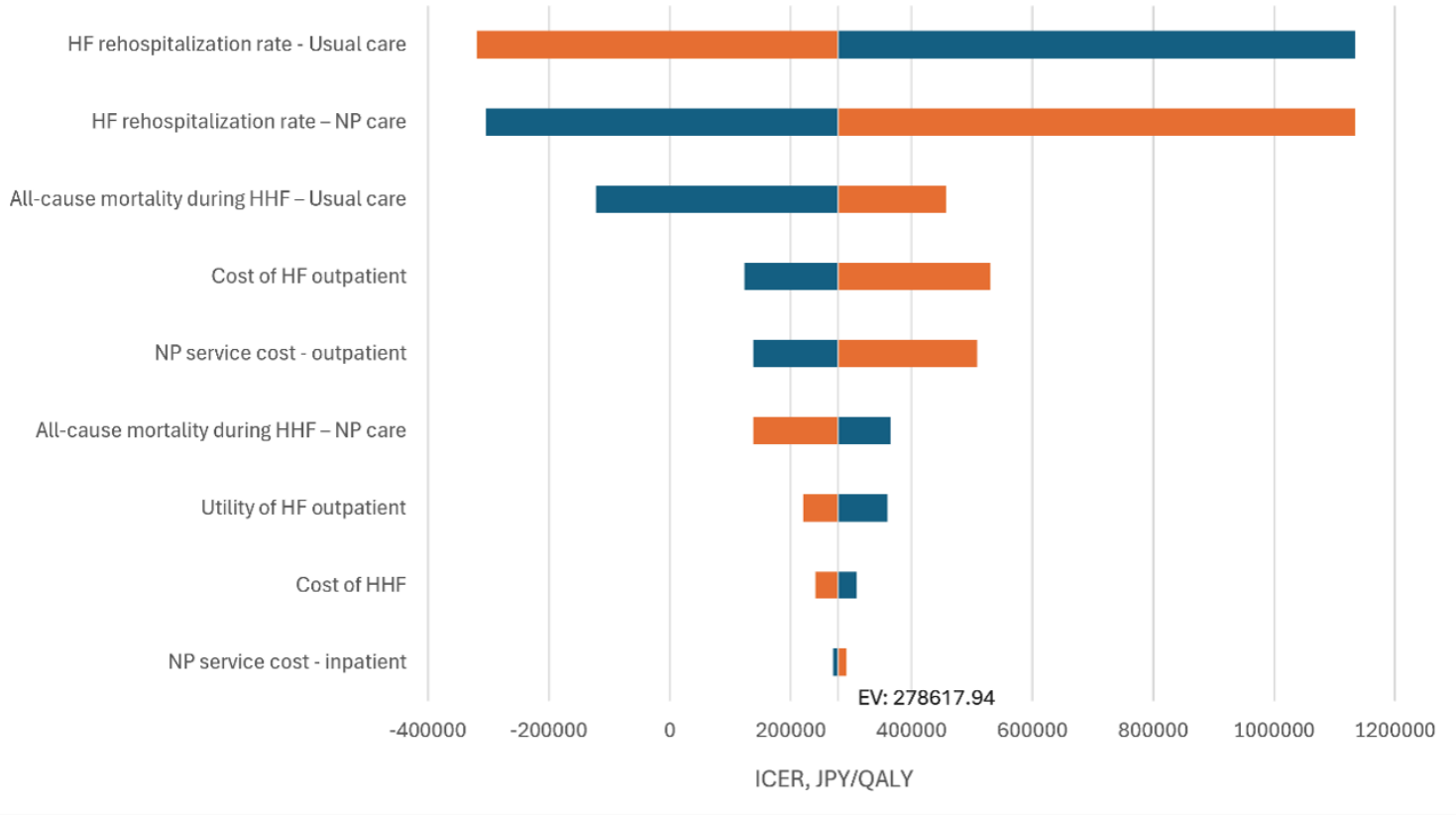


Figure 2

Tornado diagram from one-way sensitivity analyses showing incremental NMB for NP-led care versus usual care. Abbreviations: HF, heart failure; HHF, hospitalization for heart failure; NP, nurse practitioner; EV, expected value; ICER, incremental cost-effectiveness ratio; JPY, Japanese yen; QALY, quality-adjusted life years.

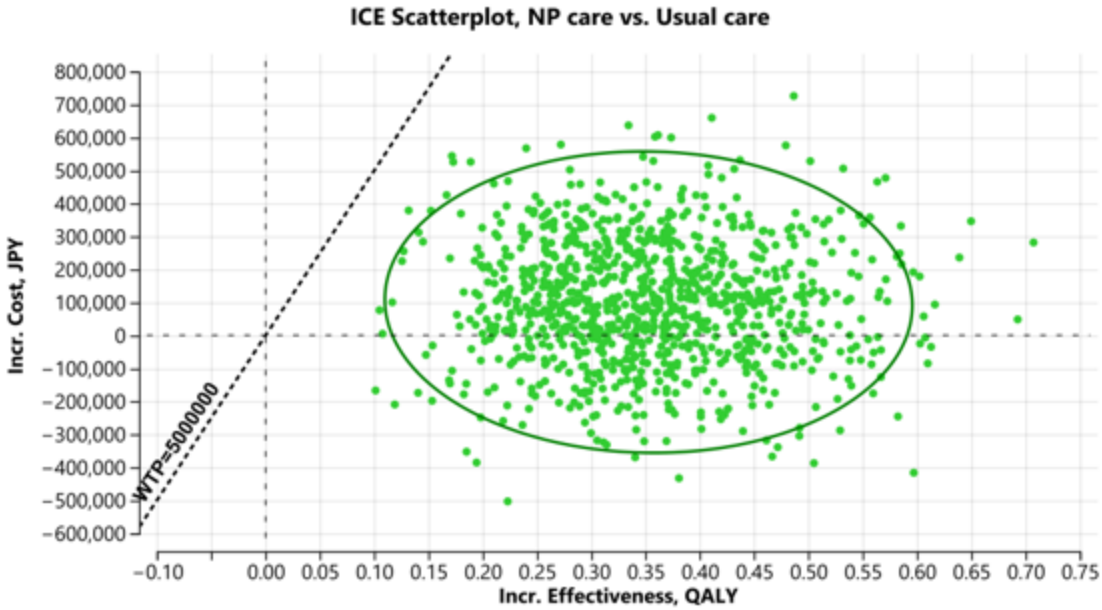


Figure 3

Incremental cost-effectiveness (ICE) scatterplot from the probabilistic sensitivity analysis comparing HF treatment with and without NP-led care. Abbreviations: NP, nurse practitioner; JPY, Japanese yen; WTP, willingness to pay; QALY, quality-adjusted life years; Incr., incremental.

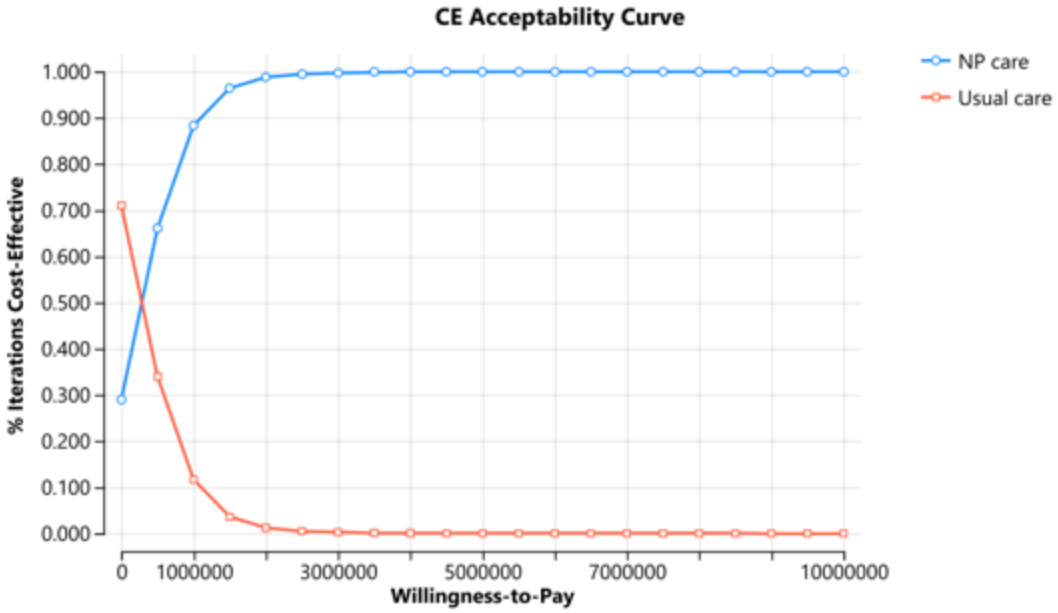


Figure 4

Cost-effectiveness acceptability curve comparing HF treatment with and without NP-led care. Abbreviations: CE, cost-effectiveness; NP, nurse practitioner.

Supplementary Files

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- Additionalfile1.docx