Research Square

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Prehospital Transport During Advanced Respiratory Support: An International Survey and Prospective Feasibility Evaluation of Portable External Power (HERMES Phase I-II Study)

SATHEESH MUNUSAMY
Hamad Medical Corporation
Francisco J Gil Martín
Osakidetza
Francisco J. Lucas Galán Francisco J. Lucas Galán
University of Castilla-La Mancha
Alejandro Ubeda
Hospital Punta de Europa, Spain
Asier Losada Carballo
Osakidetza
J. Carretero Jiménez
Mobile Emergency Unit
Berkan Basançelebi
Istanbul Medipol University
Mohsen Sadeghi
Shahid Beheshti University of Medical Sciences
Mohammed Ahmed Senan
21 September University for Medical and Applied Sciences
Roberto Santa Cruz
Hospital Ramos Mejía
Ivan Šitum
University Hospital Centre Zagreb
Hajed M. Al-Otaibi
King Abdulaziz University
Salvatore Notaro
Ospedale Monaldi
Tarig Fadelelmoula
National University of Science and Technology
Eldhos Jacob
Father Muller Medical College Hospital

Fares Alwajeeh
Al-Razi University
José Luis Sandoval Gutierrez
Instituto Nacional de Enfermedades Respiratorias
Mostafa Elshazly
Cairo University hospitals
Kadir Burak Akgün
Mustafa Kemal University
Bushra Mina
Northern Westchester Hospital
Dorothy H. Bendah
Africa Respiratory Care Association
Roberto Adrián Núñez Cruz
Zopec Medical LLC, Blaine
Gaspar R. Chiappa
Universidad Autónoma de Chile
Antonio M. Esquinas
antmesquinas@gmail.com

Hospital General Universitario Morales Meseguer

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Abstract

Background

Ambulance transport of patients receiving high-flow nasal oxygen (HFNO), noninvasive ventilation (NIV), or invasive ventilation requires continuous respiratory support, oxygen, monitoring, and electrical power.

Objective

To describe professionals' reported NIV transport practices and evaluate the feasibility of a portable external power supply during ambulance transport involving advanced respiratory support.

Methods

Phase I was a cross-sectional survey analyzed at the response-record level. Phase II was a prospective descriptive feasibility series of 25 ambulance transports using an external power supply. Author-confirmed corrections and modality recoding were documented; physiologic trajectories were summarized descriptively without causal attribution.

Results

The survey dataset contained 224 response records. A portable transport ventilator was reported by 205 respondents (91.5%). Phase II included 25 transports involving 24 adults and one child; 22 patients received HFNO, two received rescue NIV, and one received invasive ventilation during cardiopulmonary resuscitation. Respiratory support was maintained without reported power interruption, relevant alarm, or technical failure in 25/25 transports (100%; exact 95% CI, 86.3%-100%). Investigators reported that none of the 22 HFNO cases required escalation. One patient was intubated during assistance for cardiopulmonary resuscitation.

Conclusions

Respondents reported heterogeneous transport configurations and team models. In a small uncontrolled ambulance series, portable external power was used without reported interruption, but the findings do not establish clinical effectiveness, comparative safety, prevention of escalation, or device superiority.

Clinical trial registration

ClinicalTrials.gov identifier: NCT07807189; date of registration: 25 August 2026.

Trial registration

ClinicalTrials.gov, NCT07807189. Registered 25 August 2026 (retrospectively registered).

Introduction

Noninvasive ventilation (NIV) and high-flow nasal oxygen (HFNO) are frequently initiated during acute respiratory care, including in prehospital and emergency settings.(1, 2) Patients who remain dependent on noninvasive respiratory support may require ambulance transfer, diagnostic imaging, procedures, or movement to another monitored clinical area. During these transitions, respiratory support, monitoring, oxygen delivery, electrical power, and clinical responsibility must remain continuous.

Transport of critically ill patients is a recognized high-risk process. Recommendations emphasize stabilization, trained personnel, monitoring, communication, equipment checks, and contingency planning.(3, 4) Reported adverse events include physiologic deterioration, circuit or device problems, oxygen or power limitations, and communication failures, although frequencies vary with setting, definitions, case mix, urgency, and surveillance.(5–9)

Prehospital NIV has been evaluated in randomized trials and meta-analyses, whereas published transport experience with HFNO remains more limited and is largely observational.(10, 11) Electrical continuity is especially relevant when transport requires more than one powered device, such as a ventilator, heated humidifier, or HFNO system. Portable ventilator battery duration can vary substantially according to device characteristics and ventilator settings, and prior reports have described portable external power as a means of maintaining mechanical ventilation during transport (12, 13). Clinical evidence supporting external power systems during contemporary ambulance transport remains sparse. A technical solution must therefore be considered within a broader system of patient selection, monitoring, staffing, oxygen planning, and rescue preparation.

We therefore conducted a 2-phase exploratory study. Phase I described professionals' self-reported NIV transport practices, equipment configuration, team composition, and perceived problems. Phase II evaluated portable external power during 25 ambulance transports involving HFNO, rescue NIV, or invasive ventilation during cardiopulmonary resuscitation.

Methods

Study Design

This exploratory investigation comprised 2 analytically distinct phases: an electronic cross-sectional survey and a prospective descriptive feasibility series. The response record was the unit of descriptive analysis in Phase I, and the transport episode was the unit of analysis in Phase II. The Phase I workbook contained 224 response records corresponding to 221 unique respondents; all 224 records were retained

according to the prespecified analytical approach described below. The phases were not combined statistically.

Phase I: Survey Participants and Administration

The intended population comprised health care professionals involved in NIV management or transport. The supplied electronic records were timestamped from February 20 through May 6, 2023. The available documentation did not establish the invitation denominator, recruitment channels, participating countries or institutions, reminder procedures, eligibility adjudication, or definition of a completed questionnaire. Consequently, we did not calculate a response rate or produce hospital-level or country-level estimates.

Survey Variables and Data Management

Recoverable survey items addressed transport indications, ventilator positioning and type, interface use, team composition, and categories of transport-related problems. The original questionnaire and development records were not available for this analysis. Reported problem categories were interpreted as respondents' perceptions or prior experiences, not prospectively adjudicated adverse events.

The workbook contained 224 response records corresponding to 221 unique respondents. Three identifiers occurred twice with nonidentical response patterns. In the absence of a prespecified duplicate-management rule or invitation log, all 224 response records were retained for the descriptive analysis. Direct identifiers were excluded from analytical outputs, and missing cells were treated as missing rather than negative responses.

Phase II: Prospective Descriptive Feasibility Series

Phase II comprised 25 prospectively recorded ambulance transports from units in Albacete and Bilbao. Twenty-four patients were transported from the initial site of care to the emergency department and one underwent interhospital transfer. The cohort included 24 adults and one child aged 1.6 years. A Zopec Transport UPS 90 external power supply (Zopec Medical LLC, Blaine, MN, USA), supplied as material support for the study, was used throughout transport. Albacete used a Monnal T60 transport ventilator (cases 1–8); Bilbao used a Hamilton T1 (cases 9–25). Four dedicated HFNO cases used an MR850 humidification system (Fisher & Paykel; cases 16, 20, 21, and 22). Aerosol therapy, when used, was delivered using an Aerogen vibrating-mesh system.

The technical feasibility outcome was completion of ambulance transport with uninterrupted respiratory support and without reported power interruption, relevant alarm, or technical failure. After author adjudication, modalities were recoded as HFNO in 22 cases, rescue NIV in cases 6 and 8, and invasive ventilation during cardiopulmonary resuscitation in case 7. The legacy spreadsheet code labelled most

episodes as 'VNI' and was retained only in the raw-data sheet. Investigators confirmed that case 7 was intubated during assistance. The prior 'success = absence of intubation' code was therefore not used as an analytical outcome. Technical events, operational complexity, and absence of escalation among HFNO cases were author-confirmed aggregate observations without dedicated source fields.

Investigators reported that conventional ambulance electrical power was considered insufficient for the intended respiratory-support configuration in cases 6 and 8, and the external power supply was therefore used during rescue NIV. This was a clinical and operational judgment rather than an objectively measured electrical power failure.

Implementation comprised device-specific briefing sessions for staff at both participating units and approval by each unit's clinical coordinator. These operational approvals did not substitute for research ethics review. Treating physicians rated application complexity as low in all cases using a subjective, investigator-developed, unvalidated assessment.

Statistical Analysis

Categorical survey variables are presented as counts and percentages using the supplied response records as denominators. Phase II categorical variables are reported as counts and percentages, and continuous variables as mean with standard deviation, median with interquartile range, and range where informative. The exact binomial 95% confidence interval was calculated for uninterrupted support, consistent with established interpretation of zero-event samples.(14) Paired physiologic observations were summarized descriptively with 95% confidence intervals for all transports (Table 4). Modified Borg scores were analyzed in 23 adults who were not intubated; case 7 and the 1.6-year-old child were excluded because a post-intubation Borg score and use in a very young child were not clinically interpretable. No physiologic change was attributed to the power system.

Table 4
Paired physiologic observations during ambulance transport

Variable	Before, mean ± SD	After, mean ± SD	Mean change (95% CI)
SpO_2, % (n = 25)	91.16 ± 4.31	97.88 ± 2.32	6.72 (4.62 to 8.82)
Heart rate, bpm (n = 25)	109.08 ± 13.67	107.56 ± 10.07	-1.52 (-3.84 to 0.80)
Mean arterial pressure, mmHg (n = 25)	78.52 ± 6.49	78.32 ± 6.54	-0.20 (-0.72 to 0.32)
Respiratory rate, breaths/min (n = 25)	30.68 ± 2.70	26.64 ± 2.12	-4.04 (-4.89 to -3.19)
Modified Borg score, 0–10 (n = 23)	7.30 ± 1.43	3.48 ± 0.73	-3.83 (-4.54 to -3.12)

Changes are posttransport minus pretransport. SpO_2, heart rate, mean arterial pressure, and respiratory rate include all 25 recorded transports. Modified Borg score excludes case 7 (intubated) and case 13 (age 1.6 years). Confidence intervals are descriptive and do not estimate an effect of the external power system. CI, confidence interval; SD, standard deviation; SpO_2, peripheral oxygen saturation.

Ethics and Consent

The study received favorable review from the CEIm-CEI IANIV Bioethics Committee. Phase I was a voluntary electronic survey of health care professionals that collected no patient data; ethics approval was therefore not required at the time of data collection, and the survey was subsequently reviewed by the committee under internal code EST:87/24. Phase II was approved under EST:89/24. The Phase II approval covered the 25 patient transport episodes included in the prospective pilot feasibility evaluation, and informed consent was obtained. Patient information was handled according to the participating institutions' standard clinical-record confidentiality and data-protection procedures, and only deidentified data were used for analysis.

Results

Phase I: Survey Records and Transport Practices

The supplied dataset contained 224 response records corresponding to 221 unique respondents. Three identifiers occurred twice with nonidentical response patterns; all 224 response records were retained for the descriptive analysis because no prespecified duplicate-management rule or invitation log was available. Combined diagnostic and therapeutic purposes were reported by 132 respondents (58.9%), followed by diagnostic purposes (43 [19.2%]), ward transfer (26 [11.6%]), therapeutic purposes (19 [8.5%]), and surgical procedures (4 [1.8%]) (Table 1 and Fig. 2).

Table 1
Reported transport indications and equipment configuration (N = 224 response records)

Domain	Response	n/N	%
Transport indication	Combined diagnostic and therapeutic	132/224	58.9
	Diagnostic	43/224	19.2
	Ward transfer	26/224	11.6
	Therapeutic	19/224	8.5
	Surgical procedure	4/224	1.8
Ventilator positioning	Dependent on bed or transport support	104/224	46.4
	Attached to bed or stretcher	92/224	41.1
	Placed on stand	28/224	12.5
Interface	Helmet continuous positive airway pressure	38/224	17.0
Ventilator type	Portable transport ventilator	205/224	91.5
	Intensive-care-unit-type ventilator	19/224	8.5

Percentages use the 224 supplied response records. Values describe respondent reports, not audited institutional practices.

A portable transport ventilator was reported by 205 respondents (91.5%), and an intensive-care-unit-type ventilator by 19 (8.5%). Ventilator positioning was described as dependent on the bed or transport support by 104 (46.4%), attached directly to the bed or stretcher by 92 (41.1%), and placed on a stand by 28 (12.5%). Helmet continuous positive airway pressure use was reported by 38 respondents (17.0%) (Table 1).

The multiple-response team item included physicians for 158 respondents (70.5%), nurses for 154 (68.8%), respiratory therapists for 105 (46.9%), and nursing assistants for 52 (23.2%) (Table 2 and Fig. 1). Patient-related problems were selected by 100 respondents (44.6%), equipment-related problems by 96 (42.9%), and environmental problems by 28 (12.5%) (Table 2 and Fig. 2). These categories do not represent transport-level incidence.

Table 2
Reported team composition and problem categories (N = 224 response records)

Domain	Response	n/N	%
Team composition*	Physician	158/224	70.5
	Nurse	154/224	68.8
	Respiratory therapist	105/224	46.9
	Nursing assistant	52/224	23.2
Problem category	Patient-related	100/224	44.6
	Equipment-related	96/224	42.9
	Environmental	28/224	12.5

*Multiple-response item. Problem categories are respondent reports and not transport-level incidence rates.

Phase II: Portable-Power Feasibility Series

Phase II included 25 patients, comprising 22 men and three women (cases 5, 12, and 15). Twenty-four were adults and one was a child aged 1.6 years. Mean age was 54.0 ± 23.5 years; among adults, mean age was 56.2 ± 21.2 years. The series comprised 22 HFNO episodes, two rescue-NIV episodes, and one episode of invasive ventilation during cardiopulmonary resuscitation. Seventeen transports were recorded in Bilbao and eight in Albacete. Mean transport duration was 50.0 ± 18.3 minutes; median duration was 45 minutes (IQR, 40–60; range, 23–110) (Table 3 and Fig. 3).

Table 3
Characteristics, respiratory support, equipment, and feasibility outcomes of the prospective ambulance series (N = 25)

Parameter	Result
Sex	Male, 22/25 (88%); female, 3/25 (12%; cases 5, 12, 15)
Age	All: 54.0 ± 23.5 years; range 1.6–90. Adults: 56.2 ± 21.2 years
Age group	Adults, 24; pediatric, 1 (case 13, age 1.6 years)
Center	Bilbao, 17; Albacete, 8
Respiratory support	HFNO, 22; rescue NIV, 2 (cases 6, 8); invasive ventilation during CPR, 1 (case 7)
Respiratory equipment	Monnal T60, cases 1–8; Hamilton T1, cases 9–25; MR850 dedicated HFNO system, cases 16, 20, 21, 22
Oxygen settings	HFNO: flow 54.5 ± 6.7 L/min and FiO_2 47.8% ± 9.1%. In cases 6–8, 50–60 L/min represented ventilator oxygen flow and was not pooled with HFNO flow.
Transport route	Initial site to emergency department, 24; interhospital, 1
Transport duration	50.0 ± 18.3 min; median 45 (IQR 40–60); range 23–110
Uninterrupted respiratory support	25/25 (100%); exact 95% CI 86.3%-100%; investigator-confirmed
Power interruption, relevant alarm, or technical failure	0/25 reported; no dedicated patient-level technical log
Cases 6 and 8: electrical-power assessment	Conventional ambulance electrical power was considered insufficient for the intended respiratory-support configuration; external power was therefore used during rescue NIV. This was a clinical/operational judgment, not an objectively measured electrical power failure.
HFNO escalation	0/22 reported; uncontrolled observation
Intubation during assistance	1/25, case 7 during CPR; not classified as device failure
Operational complexity	Low in 25/25 by subjective, unvalidated physician assessment

Raw values were preserved separately. Results reflect author-confirmed corrections and recoding. Technical events and operational complexity were reported by investigators without dedicated patient-level technical logs. HFNO, high-flow nasal oxygen; NIV, noninvasive ventilation; CPR, cardiopulmonary resuscitation; IQR, interquartile range.

Respiratory support was maintained without reported power interruption, relevant alarm, or technical failure in all 25 transports (100%; exact 95% CI, 86.3%-100%). Investigators reported that conventional ambulance electrical power was considered insufficient for the intended respiratory-support

configuration in cases 6 and 8, and the external power supply was therefore used during rescue NIV. This represented a clinical and operational judgment rather than an objectively measured power failure. External power was also used during invasive ventilation in cardiopulmonary resuscitation in case 7. One patient was intubated during assistance; this was not classified as a device failure. None of the 22 patients managed with HFNO was reported to require escalation to NIV or invasive ventilation. Operational complexity was subjectively rated as low by treating physicians in every episode using an unvalidated investigator-developed assessment.

Discussion

This 2-phase exploratory study identifies organizational and technical domains relevant to transport during advanced respiratory support. Survey respondents reported heterogeneous equipment positioning and team composition. In a separate uncontrolled ambulance series, investigators reported uninterrupted respiratory support in 25 transports using an external power supply, including two rescue-NIV transports and one case of invasive ventilation during cardiopulmonary resuscitation.

The findings are relevant to emergency medicine because respiratory support may need to continue from prehospital care through emergency department evaluation and during subsequent transfers. Transport should be managed as continuation of resuscitative care. Before departure, clinicians should reassess suitability for NIV or HFNO, establish escalation and rescue plans, verify interface stability, estimate oxygen and power reserves, and ensure monitoring and staff competencies appropriate to anticipated deterioration.(3, 4, 15)

The feasibility series addresses one component of a larger transport system: electrical continuity. Previous bench and clinical reports show that ventilator autonomy is device- and setting-dependent and that portable power can maintain ventilation during transport, but these observations do not establish superiority of one power strategy over another.(12, 13) In cases 6 and 8, investigators judged conventional ambulance electrical power to be insufficient for the intended respiratory-support configuration; this was an operational judgment rather than a measured power failure. These episodes and the cardiopulmonary-resuscitation episode illustrate circumstances in which external power may be operationally useful, but they do not establish that the external power source prevented deterioration, intubation, or equipment failure. Similarly, the absence of reported escalation among 22 HFNO cases cannot be interpreted causally. There was no comparison with standard ambulance power, internal batteries, or another external power system.

Zopec Medical LLC supplied the portable external power system and provided device-related training and technical support. The company had no role in study design, patient selection, data collection, data access, statistical analysis, interpretation of the results, or the decision to submit the manuscript. Two coauthors have disclosed relationships with Zopec Medical, one as an employee/Product Engineer and one as a clinical advisor/collaborator; identifying details are provided on the separate title page.

Limitations

Phase I is limited by an undocumented sampling frame, unavailable recruitment details, absent questionnaire-development records, possible duplicate responses, and self-report bias. Phase II is limited by 25 episodes, mixed adult and pediatric populations, absence of a comparator, retrospective author adjudication of modality labels, and lack of patient-level battery charge, autonomy, alarm, and technical-event logs. The complexity rating was subjective and unvalidated. The physiologic dataset includes values recorded for an intubated patient and a very young child, limiting interpretation. These limitations prevent estimates of device effectiveness, comparative safety, prevention of escalation, or generalizability.

Future studies should prospectively register consecutive transports and record patient diagnosis and severity, support settings, oxygen consumption, all connected devices, battery charge before and after transport, transport duration, delays, alarms, interruptions, rescue interventions, and independently adjudicated clinical and technical events. Comparative evaluation against standard internal-battery practice or another external power strategy is required before practice recommendations can be made.

Why Should an Emergency Physician Be Aware of This?

Patients receiving HFNO, NIV, or invasive ventilation may require ambulance transport before respiratory failure is fully stabilized. In this small prospective series, external power was used during 25 transports without reported interruption, but the evidence does not establish clinical benefit or device superiority. Emergency physicians should plan monitoring, oxygen and power reserves, trained accompaniment, and rescue or escalation before departure.

Conclusions

Transport of patients receiving advanced respiratory support requires continuity of ventilation or HFNO, oxygen delivery, monitoring, and electrical power. In this exploratory two-phase study, professionals reported heterogeneous transport practices, while a separate 25-transport feasibility series documented uninterrupted respiratory support during use of portable external power. These findings support further prospective comparative investigation with device-level power logging and predefined clinical and technical outcomes; they do not establish clinical effectiveness, comparative safety, prevention of escalation, or device superiority.

Declarations

Funding

The authors declare that no funds, grants, or other financial support were received for conducting this study or preparing this manuscript. Zopec Medical LLC supplied the portable external power system and provided device-related training and technical support.

Role of the manufacturer: Zopec Medical LLC, as a company, provided the portable external power system and device-related training and technical support but had no role in study design, patient selection, data collection, data access, statistical analysis, interpretation of the results, or the decision to submit the manuscript. Contributions of individual coauthors affiliated with or serving as advisors to Zopec Medical are reported separately in the author-contribution and competing-interest statements.

Competing interests

One coauthor (R.A.N.C.) is an employee of Zopec Medical LLC and works as a Product Engineer in medical batteries. A second coauthor (D.H.B.) serves as a clinical advisor/collaborator with Zopec Medical. The remaining authors declare that they have no relationships with Zopec Medical or a Zopec distributor and no other competing interests.

Ethics approval

This study was performed in accordance with the principles of the Declaration of Helsinki. Phase I was a voluntary electronic survey of health care professionals that collected no patient data; ethics approval was therefore not required at the time of data collection. The study was reviewed and approved by the CEIm-CEI IANIV Bioethics Committee (Phase I: approval code EST:87/24; Phase II: approval code EST:89/24; date of approval: 14 May 2024).

Consent to participate

Phase I: Participation in the electronic survey was voluntary, and informed consent was obtained from all individual respondents before they completed the questionnaire. Phase II: Informed consent was obtained from all individual patients included in the study or, when a patient was unable to consent, from a legal representative; for the pediatric patient, consent was obtained from the parent(s) or legal guardian.

Consent for publication

Not applicable. The manuscript contains no individually identifiable patient data or images.

Clinical trial registration

ClinicalTrials.gov identifier: NCT07807189; date of registration: 25 August 2026.

Data availability

Deidentified individual participant data underlying the reported study results may be made available to qualified researchers upon reasonable request, subject to approval by the HERMES Steering Committee, applicable ethics requirements, institutional policies, participant consent provisions, data-protection requirements, and, when required, a data-use agreement. Data that cannot be adequately deidentified or

shared under applicable ethical, legal, or institutional requirements will not be provided. Available supporting information may include the study protocol and analytic code.

Author contributions

SM: Methodology, Investigation, Data curation, Writing – original draft, Writing – review & editing.

FJGM: Methodology, Investigation, Data curation, Writing – original draft, Writing – review & editing.

FJLG: Methodology, Investigation, Data curation, Writing – original draft, Writing – review & editing.

AU: Methodology, Investigation, Data curation, Writing – original draft, Writing – review & editing.

ALC: Methodology, Investigation, Data curation, Writing – original draft, Writing – review & editing.

JCJ: Writing – original draft, Writing – review & editing.

BB: Methodology, Writing – original draft, Writing – review & editing.

MS: Writing – original draft, Writing – review & editing.

MAS: Writing – original draft, Writing – review & editing.

RSC: Writing – original draft, Writing – review & editing.

IŠ: Writing – original draft, Writing – review & editing.

HMAO: Writing – original draft, Writing – review & editing.

SN: Writing – original draft, Writing – review & editing.

TF: Writing – original draft, Writing – review & editing.

EJ: Writing – original draft, Writing – review & editing.

FA: Writing – original draft, Writing – review & editing.

JLSG: Writing – original draft, Writing – review & editing.

ME: Writing – original draft, Writing – review & editing.

KBA: Writing – original draft, Writing – review & editing.

BM: Writing – original draft, Writing – review & editing.

DHB: Writing – original draft, Writing – review & editing.

RANC: Writing – original draft, Writing – review & editing.

GRC: Formal analysis, Writing – original draft, Writing – review & editing.

AME: Conceptualization, Methodology, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Supervision, Project administration.

All authors read and approved the final manuscript.

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Figures

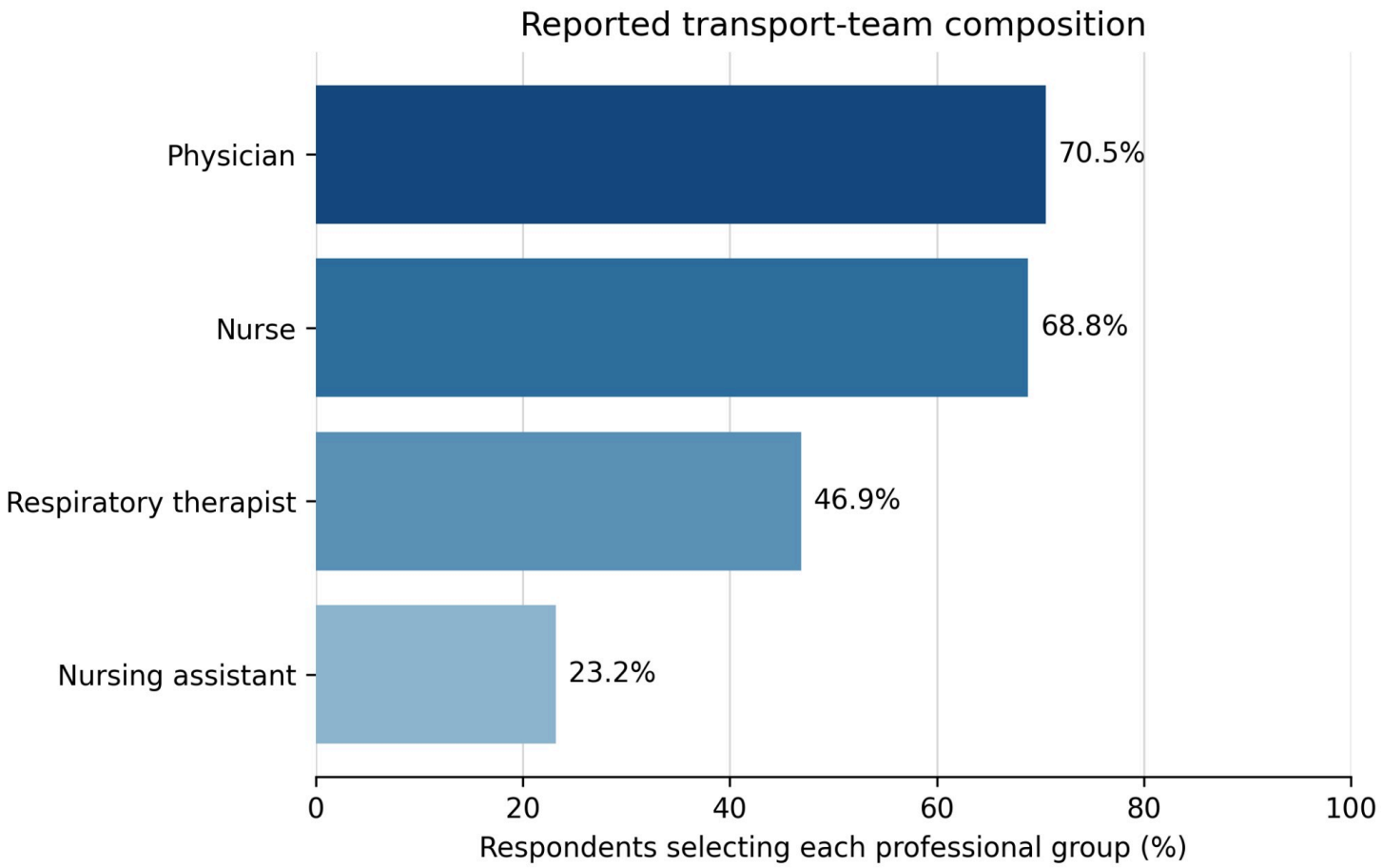


Figure 1

Reported transport-team composition. The questionnaire allowed multiple selections; percentages use 224 response records as the denominator.

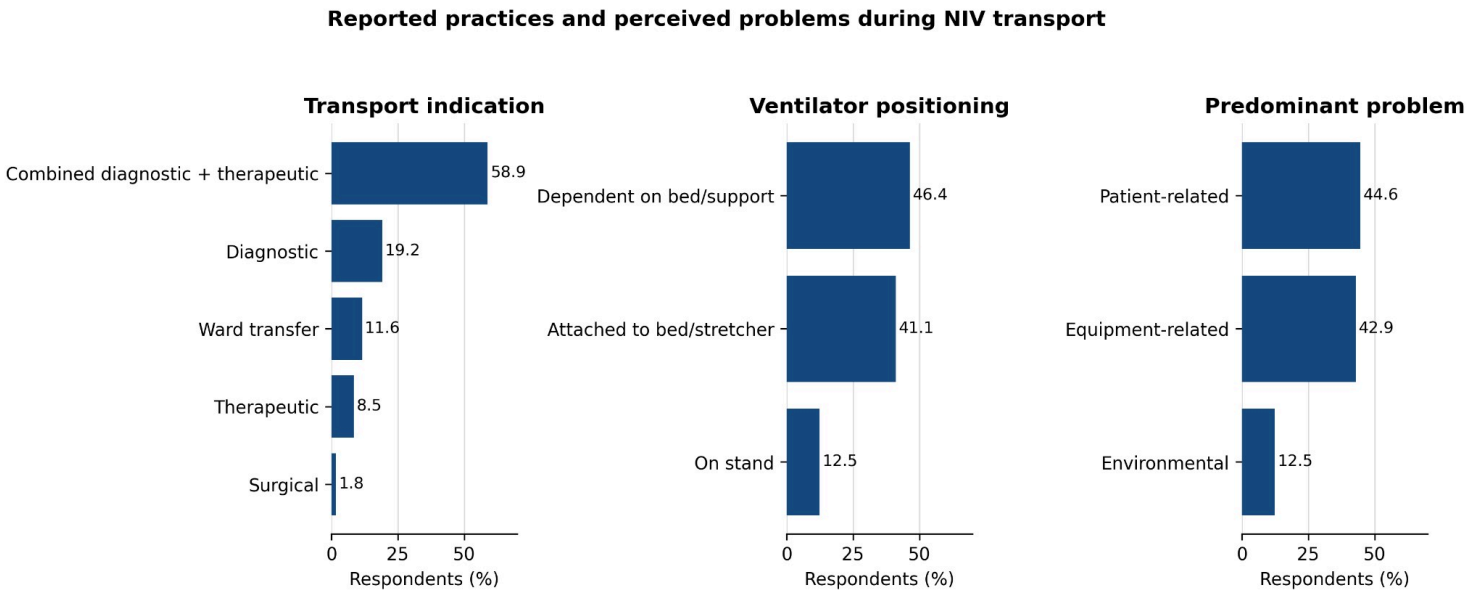


Figure 2

Reported transport indications, ventilator positioning, and predominant problem categories. Problem categories reflect respondent reports and do not represent prospectively adjudicated adverse-event incidence.

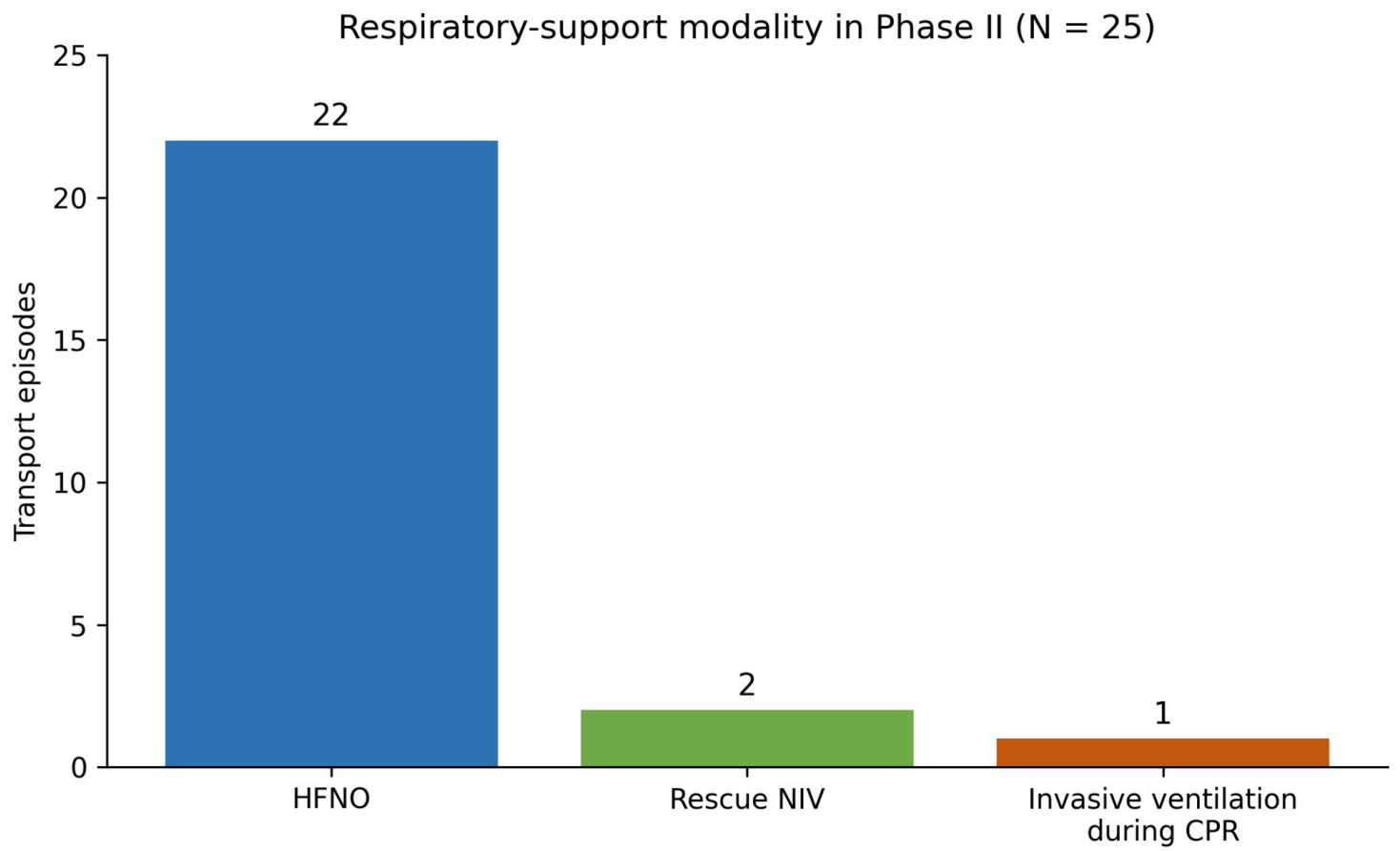


Figure 3

Respiratory-support modalities in the Phase II ambulance series. HFNO, high-flow nasal oxygen; NIV, noninvasive ventilation; CPR, cardiopulmonary resuscitation.

Supplementary Files

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- 04SupplementaryInformation.docx