Journal of Frontiers in Multidisciplinary Research

Hybrid Rehabilitation Models Combining In-Clinic and Home-Based Therapy for Complex Neurological Conditions

Venkata Amar Nuthalapati
Independent Practitioner, Home Health Physical Therapy, Maryland, United States

* Corresponding Author: **Venkata Amar Nuthalapati**

Article Info

E-ISSN: 3050-9726
P-ISSN: 3050-9718
Volume: 04
Issue: 01
January - June 2023
Received: 23-04-2023
Accepted: 25-05-2023
Published: 27-06-2023
Page No: 622-627

Abstract
Hybrid rehabilitation models combining in-clinic and home-based therapy address resource constraints and the heterogeneous needs of patients with complex neurological conditions. Each arm has independent support: telerehabilitation, early supported discharge, and caregiver-mediated exercise carry Cochrane-level evidence, while in-clinic intensity and task-specific training remain standard for motor recovery. No integrative framework, however, prescribes how dose, content, timing, and outcome measurement should be allocated across settings when stroke, traumatic brain injury, progressive disease, and fall risk overlap in a single patient. This paper synthesises fifteen high-quality references and proposes a five-component hybrid framework: phase-gate architecture, dose-allocation logic, caregiver-integration tiers, a remote-capable outcomes battery, and safety guardrails. Application to stroke, polytrauma, progressive neurological disease, and geriatric falls populations is mapped. Implications for civilian home-health physical therapy practice and cost-effectiveness modelling are discussed.

DOI: https://doi.org/10.54660/.JFMR.2023.4.1.622-627

Keywords: caregiver-mediated exercise, home health, hybrid rehabilitation, neurorehabilitation, telerehabilitation

1. Introduction

Patients with complex neurological conditions rarely fit into a single rehabilitation setting. A geriatric stroke survivor with prior traumatic brain injury, mild cognitive impairment, and a recent fall presents a problem that no isolated in-clinic episode and no isolated home program is designed to solve. Acute-care discharge is faster than a decade ago. Outpatient capacity is constrained. Family caregivers are increasingly expected to deliver therapy content. At the same time, the evidence base for telerehabilitation, early supported discharge, and home-delivered exercise has matured to the point where home delivery is no longer a fallback but a clinically defensible primary mode for many therapy components.

The result is a system in which therapy is increasingly delivered across two settings without an integrative model that says how to do it well. Clinicians design hybrid pathways case by case, drawing on local resources, payer rules, and clinical intuition. Published frameworks treat the in-clinic arm and the home arm as two independent literatures.

This paper has three aims. First, it synthesises the strongest current evidence for each arm of a hybrid model. Second, it identifies the integration gap that single-setting research has left open. Third, it proposes a structured five-component framework for hybrid neurorehabilitation that is implementable in civilian home-health physical therapy practice and that can be specialised to stroke, traumatic brain injury and polytrauma, progressive neurological disorders, and geriatric patients with falls comorbidity.

2. Methods

This paper is a structured narrative review with conceptual framework synthesis. A literature search was performed across PubMed, the Cochrane Library, OpenAlex, and Semantic Scholar between January 2010 and April 2026, restricted to peer-reviewed publications in English. Search terms combined “stroke”, “traumatic brain injury”, “rehabilitation”,

"telerehabilitation", "home-based", "hybrid", "early supported discharge", "caregiver-mediated", and "outcomes measurement". Reference lists of included reviews were screened for additional sources. Studies were eligible if they were systematic reviews, meta-analyses, large randomised trials, authoritative clinical guidelines, or descriptive accounts of established systems of care directly relevant to the in-clinic, transition, or home-based phases of neurorehabilitation. Predatory journals, Beall-listed sources, and publications without verifiable DOIs or PubMed IDs were excluded.

Fifteen sources met the inclusion criteria and form the citation backbone of this review. The framework was developed iteratively against this evidence and against US home-health physical therapy practice constraints.

3. Evidence for the Home Arm

3.1. Telerehabilitation Non-Inferiority

The strongest single piece of evidence for the home arm in stroke is Cramer *et al*. 2019, an eleven-site non-inferiority randomised trial of one hundred twenty-four adults that compared a six-week home telerehabilitation program with matched in-clinic therapy and found equivalent gains on the upper-extremity Fugl-Meyer Assessment in both acute and chronic phases [3]. The Cochrane review by Laver *et al*. 2020 reached the same conclusion at synthesis level: telerehabilitation produced outcomes that were not inferior to in-person care across activities of daily living and motor function endpoints, with no signal of harm [2]. A more recent meta-analysis by Do *et al*. 2025 confirmed that home-based rehabilitation matches facility-based rehabilitation for activities of daily living and outperforms usual care [13]. Together these three sources establish that the home arm can carry primary therapy content for stroke patients, not only adjunctive content.

3.2. Caregiver-Mediated Exercise as a Dose Extender

Caregiver-delivered exercise is now a recognised strategy to extend therapy dose without proportional clinician hours. The Cochrane review by Vloothuis *et al*. 2016 established feasibility and safety [7]. The systematic review and meta-analysis by Choo *et al*. 2022 demonstrated that structured caregiver-mediated programs improve activities of daily living and reduce post-stroke depression [6]. These findings convert the family caregiver from a passive observer into a defined therapeutic resource within a hybrid model. The implication is structural: a hybrid framework should treat caregiver capacity as a tunable parameter, not an unmodelled side-channel.

3.3. Falls Prevention in Community Settings

Falls prevention is a separate but coupled stream of evidence. Sherrington *et al*. 2019 pooled one hundred eight randomised trials with twenty-three thousand four hundred seven participants and reported that home- and community-delivered balance and functional exercise reduces fall rate by about twenty-three percent [4]. Liu-Ambrose *et al*. 2019 added that an Otago-style home program in high-risk older fallers cut subsequent fall rate by thirty-six percent over twelve months [5]. For complex neurological patients, falls comorbidity is rarely separable from primary diagnosis. The hybrid framework must therefore embed falls-prevention content within the home phase rather than treat it as a parallel program.

4. Evidence for the Clinic Arm and the Transition

4.1. The In-Clinic Therapy Standard

The in-clinic phase remains the setting in which high-intensity, repetitive, task-specific training is most reliably delivered. Veerbeek *et al*. 2014 synthesised four hundred sixty-seven randomised trials of post-stroke physical therapy and concluded that high-intensity, task-specific, and circuit-training interventions produce the strongest motor outcomes [9]. Lohse *et al*. 2014 quantified the dose-response relationship across stroke trials and reported a small to moderate effect size of g equal to zero point three five favouring more therapy [8]. The American Heart Association and American Stroke Association guideline by Winstein *et al*. 2016 codifies these findings into formal practice standards for adult stroke rehabilitation, including pre-discharge functional assessment and structured care transitions [10].

4.2. Early Supported Discharge as the Bridge

The transition phase between hospital and home is mapped most rigorously by the early supported discharge evidence base. Langhorne and Baylan 2017, in a Cochrane review of seventeen trials with two thousand four hundred twenty-two stroke patients, showed that an early supported discharge service delivered by a coordinated multidisciplinary team reduces hospital length of stay by approximately five days and improves long-term functional independence [1]. The Lancet review by Langhorne, Bernhardt, and Kwakkel 2011 frames this evidence within the broader stroke rehabilitation literature and remains the canonical narrative scaffold for any hybrid-model proposal [11].

4.3. The Counterweight on Dose and Timing

A hybrid model that simply maximises dose by stacking clinic and home content is not safe by default. The AVERT trial by Bernhardt *et al*. 2015, a phase III randomised study of two thousand one hundred four stroke patients, found that very early high-dose mobilisation within twenty-four hours of stroke onset worsened three-month outcomes compared with usual early mobilisation [12]. The implication for hybrid design is critical: dose-titration logic must be explicit and time-anchored, not opportunistic.

4.4. Synthesis of Cross-Setting Evidence

Table I summarises the evidence positioning of each setting and transition.

Table 1: Evidence Positioning Across Settings

Phase	Strongest evidence type	Key finding	Implication for hybrid model
In-clinic	Meta-analyses [8], [9]	High-intensity task-specific training drives motor recovery	Preserve as primary site for skilled high-dose work
Transition	Cochrane review [1]	ESD reduces length of stay and improves independence	Structured, coordinated, multidisciplinary handoff is mandatory
Home, telerehab	RCT and Cochrane [2], [3]	Non-inferiority for ADL and motor function	Eligible to carry primary therapy content, not only adjunct
Home, caregiver-mediated	Cochrane and meta-analysis [6], [7]	Improves ADL and depression	Caregiver becomes a defined therapy resource
Home, falls prevention	Meta-analysis [4], RCT [5]	23 to 36 percent fall-rate reduction	Embedded, not parallel, in the home phase
Dose ceiling	Phase III RCT [12]	Excessive early dose can harm	Dose-titration must be time-anchored

5. Proposed Hybrid Framework

The framework has five components. Each component is grounded in the synthesised evidence and is designed to be implementable inside a US home-health physical therapy practice without specialised hospital infrastructure.

5.1. Component 1: Phase-Gate Architecture

Three sequential phases are defined: an acute clinical phase, a structured transition phase, and a sustained home phase. Each phase is bounded by clinical gating criteria rather than by a fixed calendar window.

1. Acute clinical phase: Begins at index event. Ends when the patient is medically stable, can tolerate at least forty-five minutes of cumulative therapy per day, and has had a formal pre-discharge ADL and IADL assessment in line with the AHA and ASA guideline [10]. Primary site is in-clinic.

2. Structured transition phase: A four to six week window aligned with the early supported discharge model [1]. A coordinated multidisciplinary team continues therapy with progressive home delivery and decreasing clinic frequency. The transition is closed when the patient has demonstrated safe home performance of three core tasks: transfers, gait, and one prioritised activity of daily living.

3. Sustained home phase: Open-ended. Therapy is delivered through a combination of telerehabilitation, periodic in-clinic touchpoints, and structured caregiver-mediated work. The phase is governed by a quarterly outcomes review and discharge criteria tied to outcome stability, not therapy hours.

5.2. Component 2: Dose-Allocation Logic Across Settings

Therapy dose is allocated by content type, not by total minutes. Three content types are defined and assigned to settings according to where the evidence places them.

1. High-skill, high-intensity, task-specific work: Allocated to the in-clinic site during the acute phase, then progressively to telerehabilitation in the home phase as patients gain independence and reliable digital access. Anchor evidence: Veerbeek *et al*. 2014 [9]; Cramer *et al*. 2019 [3].

2. Volume work: Repetitive practice, range-of-motion, balance circuits, and home-exercise progression. Allocated to the home phase from the transition onward, with a defined caregiver role where applicable. Anchor evidence: Choo *et al*. 2022 [6]; Vloothuis *et al*. 2016 [7].

3. Functional generalisation: Performance of trained tasks in the home environment. Allocated entirely to the home phase from the transition onward. Anchor evidence: Sherrington *et al*. 2019 [4]; Liu-Ambrose *et al*. 2019 [5].

A dose-titration rule is overlaid on this allocation: any increase in cumulative dose in the first two weeks post-event must respect the AVERT signal that very early high-dose mobilisation can worsen outcomes [12]. Dose escalation is therefore staged in two-week increments anchored to symptom-limited tolerance rather than to a fixed protocol.

5.3. Component 3: Caregiver-Integration Tiers

Caregiver capacity varies and must be assessed, not assumed. Three tiers are defined.

1. Tier 1, observer: No structured therapy delivery. Caregiver is briefed on safety, fall prevention, and red flags only. Used when capacity is low or when caregiver presence is intermittent.

2. Tier 2, prompted assistant: Caregiver delivers a written or video-prompted home-exercise program two to three times per week, with weekly clinician check-in. Volume work and functional generalisation are delegated. Anchor evidence: Vloothuis *et al*. 2016 [7].

3. Tier 3, trained co-therapist: Caregiver completes a structured training block during the transition phase and delivers daily session content with biweekly clinician supervision. Used when caregiver capacity, motivation, and patient acuity all support it. Anchor evidence: Choo *et al*. 2022 [6].

Tier assignment is reviewed at each phase gate and can be downgraded or upgraded in response to outcomes data.

5.4. Component 4: Remote-Capable Outcomes Battery

Outcomes measurement is the weakest link in current hybrid practice because most validated measures were developed in clinic settings. The proposed battery uses three layers.

1. Core measures, clinician-administered, clinic site: Fugl-Meyer Assessment for upper-extremity stroke recovery, Berg Balance Scale, and the Functional Independence Measure. Administered at acute discharge, at transition close, and at quarterly home-phase reviews.

2. Functional measures, clinician-administered, home or telehealth*:* Timed Up and Go, ten-metre walk test, and Barthel Index. Administered every two to four weeks across the transition and home phases.

3. Patient and caregiver-reported measures, asynchronous: A short structured falls log, a weekly self-rated function item set, and a caregiver-reported exercise adherence log. Used continuously through the home phase.

Validation work to formally establish remote-administration

psychometrics for each measure is identified as a downstream research priority.

5.5. Component 5: Safety Guardrails

Three guardrails operate continuously across settings.

1. Falls and red-flag triage: Embedded in the home phase per the Sherrington 2019 evidence base [4], with escalation criteria triggering an in-clinic review.

2. Dose-tolerance monitoring: A weekly review of cumulative therapy minutes and patient-reported fatigue, designed to catch the AVERT-style early-overdose risk [12].

3. Cognitive and behavioural screening: Particularly relevant for traumatic brain injury and progressive neurological disease, where therapy adherence is a function of cognitive load. A short biweekly cognitive screen flags drift before it surfaces in functional measures.

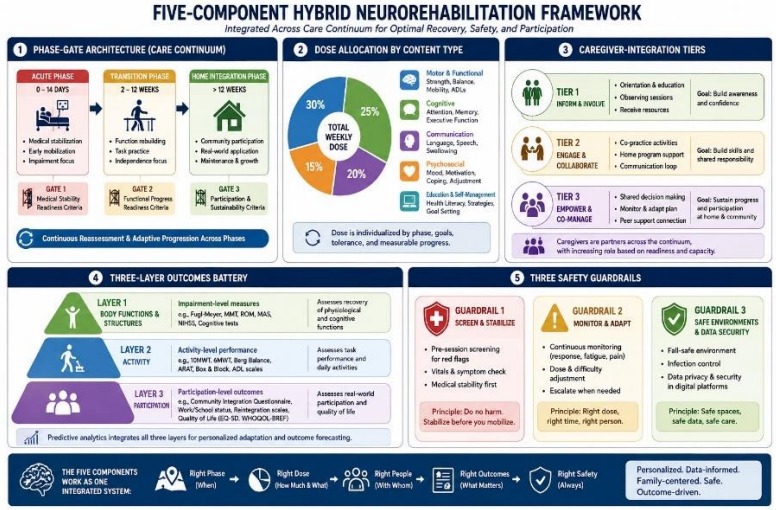

Fig 1: Five-component hybrid neurorehabilitation framework, showing phase-gate architecture (acute, transition, home), dose allocation by content type, caregiver-integration tiers 1 to 3, the three-layer outcomes battery, and the three safety guardrails.

6. Application to Complex Neurological Populations

The framework is designed to specialise to the populations most often encountered in civilian home-health physical therapy practice. Table II maps the specialisation parameters.

Table 2: Framework Specialisation by Population

Population	Primary phase emphasis	Caregiver tier default	Outcomes battery emphasis	Safety guardrail emphasis
Stroke, sub-acute	Transition heavy	Tier 2 to 3	FMA-UE, BBS, FIM	Dose-tolerance, falls
Stroke, chronic	Home heavy	Tier 2	FMA-UE, TUG, Barthel	Falls
TBI and polytrauma	All three phases active	Tier 1 to 2	FIM, cognitive screen, behavioural	Cognitive, dose-tolerance
Progressive neurological disease	Home heavy, slow gates	Tier 2 to 3	TUG, Barthel, falls log	Falls, cognitive
Geriatric, falls comorbid	Home heavy	Tier 2	BBS, TUG, falls log	Falls (primary)

6.1. Stroke, Sub-Acute and Chronic

For sub-acute stroke patients, the transition phase is the operational centre of gravity. Early supported discharge evidence [1] supports an active multidisciplinary handoff with progressive home shift. For chronic stroke patients, the home phase becomes dominant, and Cramer *et al*. 2019 supports the use of telerehabilitation as the primary delivery channel [3].

6.2. Traumatic Brain Injury and Polytrauma

Traumatic brain injury and polytrauma require all three phases to remain active for longer durations. The Department of Veterans Affairs polytrauma system of care, described by Lamberg *et al*. 2018 [15], provides the most developed institutional model. Civilian home-health physical therapy lacks the integrated infrastructure of the VA polytrauma centres but can replicate the system-of-care logic at smaller scale by using the framework's coordinated transition phase and explicit cognitive-screening guardrail.

6.3. Progressive Neurological Disorders

For progressive neurological disorders, phase gates are slower and outcomes targets are weighted toward function preservation rather than recovery. Caregiver-integration Tier 3 is used preferentially, with the caregiver becoming the consistent delivery channel as clinical contact frequency declines.

6.4. Geriatric Patients with Falls Comorbidity

The geriatric falls-comorbid population is the population in which the home phase carries the heaviest load. The Sherrington 2019 and Liu-Ambrose 2019 evidence base [4], [5] supports a falls-prevention-first home program with periodic clinic touchpoints to escalate complexity.

7. Economic and Policy Implications

The cost-effectiveness literature on telerehabilitation in neurological and cardiological diseases, synthesised by Lamberti *et al*. 2022, reports per-patient savings when telerehabilitation substitutes for in-clinic delivery in stroke

[14]. No published economic evaluation has modelled a true hybrid pathway. The framework presented here generates a structured economic question: what is the cost-effectiveness of a hybrid pathway versus single-setting delivery, controlling for caregiver tier, dose allocation, and outcome trajectory? Health-system policy decisions on home-health reimbursement, telerehabilitation parity, and caregiver-training credit hinge on this question.

For US home-health physical therapy specifically, two policy levers are immediately relevant. First, reimbursement for caregiver-training contact time, which is currently fragmented across payers, would convert Tier 3 caregiver integration from a clinician-discretionary practice into a reimbursable component of a hybrid pathway. Second, telerehabilitation reimbursement parity, which expanded during the COVID-19 emergency and has partially persisted, is a precondition for the dose-allocation logic described in Section V-B.

8. Limitations

Three limitations are acknowledged. First, this is a structured narrative review, not a systematic review, and the citation set is intentionally bounded to anchor a framework rather than to exhaust the literature. Second, the framework has not yet been prospectively validated; the recommended next step is a feasibility trial in a single home-health practice with a defined patient mix. Third, validated remote-administration psychometrics for several core outcome measures remain incomplete, which constrains the rigour of the home-phase outcomes layer until further validation work is published.

9. Conclusions

Hybrid rehabilitation models that combine in-clinic and home-based therapy are no longer an optional adjunct to neurorehabilitation. They are becoming the dominant clinical reality for patients with complex neurological conditions, but the evidence base treats the in-clinic and home arms in isolation. This paper proposes a five-component framework that integrates phase-gate architecture, dose-allocation logic, caregiver-integration tiers, a remote-capable outcomes battery, and safety guardrails. The framework specialises to stroke, traumatic brain injury and polytrauma, progressive neurological disease, and geriatric falls populations, and it is implementable in civilian home-health physical therapy practice without specialised hospital infrastructure. Prospective feasibility testing, remote-administration psychometric validation of the outcomes battery, and economic modelling of true hybrid pathways are identified as the most urgent next steps.

Acknowledgement

No external funding supported this work. The author thanks the home-health patients, caregivers, and clinical colleagues whose practice context informed the framework design.

References

1. Langhorne P, Baylan S; Early Supported Discharge Trialists. Early supported discharge services for people with acute stroke. Cochrane Database Syst Rev. 2017;(7):CD000443. doi:10.1002/14651858.CD000443.pub4.
2. Laver KE, Adey-Wakeling Z, Crotty M, Lannin NA, George S, Sherrington C. Telerehabilitation services for stroke. Cochrane Database Syst Rev. 2020;(1):CD010255. doi:10.1002/14651858.CD010255.pub3.
3. Cramer SC, Dodakian L, Le V, See J, Augsburger R, McKenzie A, *et al*. Efficacy of home-based telerehabilitation vs in-clinic therapy for adults after stroke: A randomized clinical trial. JAMA Neurol. 2019;76(9):1079-1087. doi:10.1001/jamaneurol.2019.1604.
4. Sherrington C, Fairhall NJ, Wallbank GK, Tiedemann A, Michaleff ZA, Howard K, *et al*. Exercise for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2019;(1):CD012424. doi:10.1002/14651858.CD012424.pub2.
5. Liu-Ambrose T, Davis JC, Best JR, Dian L, Madden K, Cook W, *et al*. Effect of a home-based exercise program on subsequent falls among community-dwelling high-risk older adults after a fall: A randomized clinical trial. JAMA. 2019;321(21):2092-2100. doi:10.1001/jama.2019.5795.
6. Choo WT, Jiang Y, Chan KGF, Ramachandran HJ, Teo JYC, Seah CWA, Wang W. Effectiveness of caregiver-mediated exercise interventions on activities of daily living, anxiety and depression post-stroke rehabilitation: A systematic review and meta-analysis. J Adv Nurs. 2022;78(7):1870-1882. doi:10.1111/jan.15239.
7. Vloothuis JDM, Mulder M, Veerbeek JM, Konijnenbelt M, Visser-Meily JMA, Ket JCF, *et al*. Caregiver-mediated exercises for improving outcomes after stroke. Cochrane Database Syst Rev. 2016;(12):CD011058. doi:10.1002/14651858.CD011058.pub2.
8. Lohse KR, Lang CE, Boyd LA. Is more better? Using metadata to explore dose-response relationships in stroke rehabilitation. Stroke. 2014;45(7):2053-2058. doi:10.1161/STROKEAHA.114.004695.
9. Veerbeek JM, van Wegen E, van Peppen R, van der Wees PJ, Hendriks E, Rietberg M, Kwakkel G. What is the evidence for physical therapy poststroke? A systematic review and meta-analysis. PLoS One. 2014;9(2):e87987. doi:10.1371/journal.pone.0087987.
10. Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, *et al*. Guidelines for adult stroke rehabilitation and recovery: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2016;47(6):e98-e169. doi:10.1161/STR.0000000000000098.
11. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. Lancet. 2011;377(9778):1693-1702. doi:10.1016/S0140-6736(11)60325-5.
12. Bernhardt J, Langhorne P, Lindley RI, Thrift AG, Ellery F, Collier J, *et al*. Efficacy and safety of very early mobilisation within 24 h of stroke onset (AVERT): A randomised controlled trial. Lancet. 2015;386(9988):46-55. doi:10.1016/S0140-6736(15)60690-0.
13. Do Y, Lim Y, Jin S, Lee H. Effectiveness of home-based rehabilitation on activities of daily living in patients with stroke: Systematic review and meta-analysis. Phys Ther. 2025;105(6):pzaf044. doi:10.1093/ptj/pzaf044.

14. Lamberti N, Manfredini F, Lissom LO, Lavezzi S, Basaglia N, Straudi S. Costs and effects of telerehabilitation in neurological and cardiological diseases: A systematic review. Front Med (Lausanne). 2022;9:832229. doi:10.3389/fmed.2022.832229.
15. Lamberg EM, Lugo-Larcheveque N, DePass MC, Vital A. Department of Veterans Affairs polytrauma rehabilitation centers: A comprehensive description. J Head Trauma Rehabil. 2018;33(6):396-405. doi:10.1097/HTR.0000000000000369.