



Stroke, Socioeconomics, and Mechanical Thrombectomy: A Call for Equity in Indian Neurovascular Care

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ABSTRACT:

Acute ischemic stroke (AIS), predominantly caused by large vessel occlusion (LVO), remains a major global contributor to disability and mortality. Mechanical thrombectomy (MT), a minimally invasive endovascular procedure, has revolutionized AIS management, particularly for patients unresponsive to intravenous thrombolysis. Landmark randomized controlled trials—such as MR CLEAN, ESCAPE, DAWN, and DEFUSE-3—have confirmed the efficacy of MT, even extending the treatment window to 24 hours post-symptom onset in select cases.

Despite these clinical breakthroughs, MT remains underutilized in India, with fewer than 0.1% of eligible stroke patients receiving the intervention annually. In Rajasthan, where approximately 148,895 strokes occur each year—30% involving LVO—only 110 MT procedures had been reported by 2021, over half performed at a single centre in PMCH, Bedla, Udaipur. Barriers such as lack of awareness, economic constraints, insufficient infrastructure, and regional healthcare disparities limit access to this life-saving therapy.

The economic impact is also alarming. Stroke affects a significant portion of the working-age population, resulting in lost productivity, reduced wages, and increased caregiver burdens, ultimately leading to national productivity losses exceeding 1.02 trillion. Since it has proven clinical and cost-effectiveness, expanding access to MT should be a key public health focus.

This paper supports a comprehensive approach that includes government backing, public education, healthcare workforce development, and financial grants to expand the use of MT. These initiatives could greatly lower stroke-related illness and death, while also protecting economic productivity and enhancing quality of life for people from different socioeconomic backgrounds.

1. Introduction

Acute ischemic stroke (AIS) is a life-threatening neurological emergency caused by the sudden interruption of cerebral blood flow, most often due to

thromboembolic occlusion of a major cerebral artery. [1] AIS remains one of the foremost causes of long-term disability and mortality worldwide, placing a significant burden on healthcare systems and national economies.



Among the various subtypes of ischemic stroke, large vessel occlusions (LVOs) are particularly devastating due to their association with extensive brain infarction and severe neurological impairment. [2,3,4]

Over the past decade, the development of mechanical thrombectomy (MT) has significantly advanced the management of AIS. [5,6] This endovascular procedure involves the physical retrieval of occlusive thrombi from major cerebral arteries, offering rapid reperfusion and substantial improvements in patient outcomes. Unlike intravenous thrombolysis—which is constrained by a narrow therapeutic window and various contraindications—MT enables intervention even in patients presenting beyond the conventional time limits, provided they meet specific imaging-based eligibility criteria.[7]

This review presents a comprehensive examination of MT, including its historical development, technological progress, clinical efficacy, safety profile, and economic impact. It also critically evaluates the barriers to equitable access, particularly within the Indian context, where adoption rates remain alarmingly low despite robust evidence supporting its effectiveness. Special emphasis is placed on the state of Rajasthan as a case study to explore systemic, infrastructural, and socioeconomic challenges that hinder the widespread implementation of this life-saving therapy.

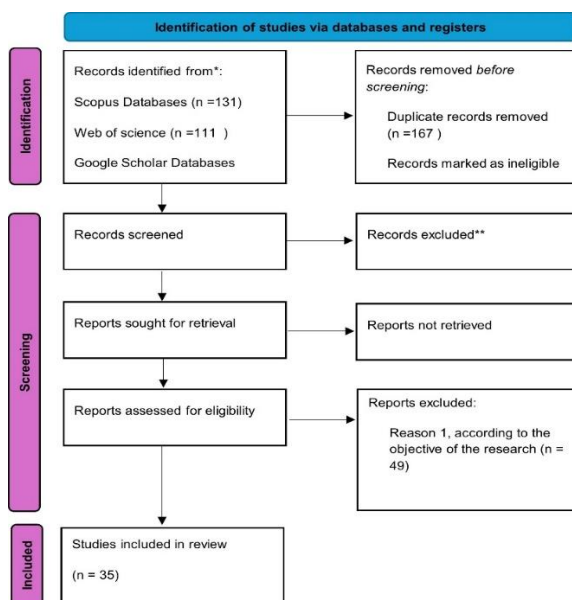


Figure 1- Methodology of data collection according to PRISMA guidelines

2. Epidemiology of Acute Ischemic Stroke and the Role of Large Vessel Occlusion

Stroke remains the second leading cause of death and the primary cause of long-term disability worldwide. Epidemiological data suggest that ischemic strokes constitute approximately 85% of all stroke cases.[8,9,10] Within this category, large vessel occlusions (LVOs)—typically involving the internal carotid artery, middle cerebral artery, or basilar artery—are particularly catastrophic, often leading to widespread brain infarction and profound neurological deficits if not treated promptly.[11,12]

The global burden of stroke continues to rise due to increasing life expectancy and the growing prevalence of risk factors such as hypertension, diabetes mellitus, dyslipidaemia, and atrial fibrillation.[9,10,12] In high-income countries, advances in prehospital triage systems and the establishment of comprehensive stroke centres have significantly improved early diagnosis and access to specialized care.[13] However, disparities in stroke management remain stark—particularly in low- and middle-income countries (LMICs) like India—due to limited access to advanced interventions such as mechanical thrombectomy.[13,14]

Timely and effective reperfusion remains the most critical determinant of favourable outcomes in AIS.[15] The advent of MT has extended the therapeutic window for intervention, with some patients now being treated up to 24 hours after symptom onset, based on advanced imaging criteria that identify salvageable brain tissue.[16] This paradigm shift emphasizes the need for rapid diagnosis, efficient referral networks, and the establishment of adequately equipped stroke centres capable of performing MT across diverse geographic and economic landscapes.[17,18]

3. Historical Evolution of Mechanical Thrombectomy

The evolution of mechanical thrombectomy (MT) represents a series of technological innovations aimed at improving outcomes for patients with large vessel occlusion (LVO) strokes.[19] In the early 2000s, the first generation of endovascular devices—such as the Merci Retriever and the Penumbra System—offered proof-of-concept that mechanical clot removal could restore cerebral blood flow. While these early tools marked an



important step forward, their success rates were modest, and complication rates remained a concern.[18,19]

A major breakthrough came with the introduction of stent retriever devices, such as the Solitaire FR and Trevo, which demonstrated significantly improved recanalization rates and procedural safety. These innovations were pivotal in transforming MT from an experimental procedure into a standard of care.[20]

A series of high-impact randomized controlled trials (RCTs)—including MR CLEAN, ESCAPE, REVASCAT, SWIFT PRIME, and EXTEND-IA—solidified MT's place in acute stroke therapy. [21] Conducted between 2014 and 2015, these trials consistently showed that MT performed within 6 hours of symptom onset resulted in markedly better functional outcomes compared to standard medical management alone.[22]

Further advancements were driven by the DAWN and DEFUSE 3 trials, which employed perfusion imaging to select patients with viable penumbral tissue. [21,22,23] These studies extended the treatment window up to 24 hours in carefully selected patients, challenging earlier notions of rigid time-based intervention and highlighting the role of tissue-based decision-making in stroke management.[24,25]

Today, MT is firmly established as a cornerstone of acute ischemic stroke treatment. Ongoing research continues to refine patient selection criteria, procedural techniques, and post-procedural care protocols to maximize benefit and expand accessibility worldwide.[26]

4. Clinical Efficacy: Evidence from Randomized Trials and Meta-Analyses

The clinical efficacy of mechanical thrombectomy (MT) in acute ischemic stroke (AIS) due to large vessel occlusion (LVO) is well-established through numerous randomized controlled trials (RCTs) and meta-analyses. These studies have consistently demonstrated that MT significantly improves functional outcomes, reduces disability, and enhances survival rates when compared to standard medical therapy alone.[27]

4.1 Early Landmark Trials and Establishment of MT as Standard of Care:

- **MR CLEAN (2015):** This pivotal trial was the first to conclusively demonstrate the superiority of MT

over medical therapy alone in patients with LVO. It reported significantly better functional outcomes at 90 days, measured by the modified Rankin Scale (mRS), in the intervention group.

- **ESCAPE, REVASCAT, SWIFT PRIME, and EXTEND-IA:** These contemporaneous trials reinforced MR CLEAN's findings. Each study demonstrated higher rates of successful recanalization, reduced neurological disability, and improved survival among patients treated with MT. Collectively, they established MT as the standard of care for patients presenting within 6 hours of symptom onset.

4.2 Extension of the Therapeutic Window:

- **DEFUSE 3 (2018):** This trial expanded the eligible treatment window to 6–16 hours using perfusion imaging to identify patients with salvageable brain tissue. It confirmed that selected patients benefit from MT even beyond the traditional 6-hour window.
- **DAWN (2018):** DAWN further extended the intervention window to 24 hours in patients exhibiting a mismatch between clinical severity and infarct volume, as determined by advanced imaging. The trial highlighted the importance of individualized, tissue-based decision-making in late-presenting stroke cases.

These trials collectively shifted the paradigm from rigid time-based treatment criteria to a more nuanced, imaging-guided approach. Meta-analyses incorporating individual patient data from these and related studies have reinforced the robust and consistent efficacy of MT across diverse patient populations, further supporting its widespread adoption as a life-saving intervention in AIS management.

5. The Prevalence of Stroke in Rajasthan and India

Stroke remains a major public health concern in India, affecting an estimated 1.78% of the population—translating to over 2.4 million cases annually. In Rajasthan alone, approximately 148,895 stroke cases occur each year, representing 0.70% of the state's total population. These figures underscore the urgent need for targeted interventions aimed at reducing the incidence and improving the management of stroke across the region.[25,26]



Ischemic stroke accounts for nearly 85% of all stroke cases in Rajasthan, mirroring national and global trends. Notably, about 80% of these cases affect individuals under the age of 60, indicating a substantial impact on the working-age population.[29] This demographic trend exacerbates both direct and indirect burdens, including loss of productivity, reduced household income, and increased financial strain on healthcare systems and families.[27,28]

Large vessel occlusion (LVO) contributes to approximately 30% of all AIS cases and is associated with significantly higher rates of disability and mortality. Data from the All India Institute of Medical Sciences (AIIMS), Jodhpur, revealed that the incidence of LVO among ischemic stroke patients increased markedly—from 16.3% before the COVID-19 pandemic to 56.2% during the pandemic period.[29,30,31] This sharp rise suggests that LVO has become an increasingly dominant contributor to ischemic stroke in Rajasthan, potentially due to pandemic-related delays in diagnosis and treatment.[32,33]

The high prevalence of LVO-associated strokes, especially among economically active individuals, underscores the need for timely interventions such as mechanical thrombectomy. Addressing this issue requires not only technological advancement but also improvements in healthcare infrastructure, stroke awareness, and access to timely, specialized care. [34,35]

6. Mechanical Thrombectomy

Mechanical thrombectomy (MT) is a minimally invasive endovascular procedure used to remove a thrombus (blood clot) from a blocked cerebral artery. It is primarily employed in the treatment of acute ischemic stroke (AIS), where a clot obstructs blood flow to a portion of the brain. The procedure involves navigating a catheter through the vascular system to the site of occlusion, where a specialized device—such as a stent retriever or aspiration system—is used to capture and extract the clot, thereby restoring perfusion to the affected brain tissue.[1-4]

MT is typically performed by interventional neuroradiologists or neurologists with expertise in endovascular techniques. Clinical evidence strongly supports its use in cases of large vessel occlusion (LVO), where prompt intervention can significantly reduce the

extent of neurological damage, improve functional outcomes, and increase survival rates.[5] The success of the procedure is highly time-dependent, with optimal outcomes observed when MT is initiated within a few hours of symptom onset.[6]

MT has emerged as a highly effective therapy for patients who are ineligible for, or unresponsive to, intravenous thrombolysis. Its advantages include a higher rate of vessel recanalization, a broader treatment window (up to 24 hours in selected cases), and a favorable safety profile when performed in appropriate clinical settings.[5,6,7]

Despite its proven benefits, MT remains underutilized in many regions due to limited awareness, high costs, and restricted access to specialized centers. Expanding MT availability requires investments in infrastructure, physician training, and public health initiatives aimed at early stroke recognition and timely referral to capable treatment facilities.[8,9]

7. Prevalence of Mechanical Thrombectomy

Despite the high burden of stroke in India, the utilization of mechanical thrombectomy (MT) remains alarmingly low.[14,15] Of the approximately 1.18 million stroke cases reported annually across the country, fewer than 3,000 to 4,000 MT procedures are performed each year. This translates to an adoption rate of less than 0.1%—a figure that starkly contrasts with the proven clinical efficacy and cost-effectiveness of the intervention. [11,12]

In Rajasthan, the situation is similarly concerning. By 2021, only 110 MT procedures had been documented in the entire state, with over 60 of these performed at a single center—PMCH, Bedla, in Udaipur. This concentration of procedures in one institution highlights the severe disparity in access and the lack of widespread capacity for advanced stroke interventions across the region.

Key factors contributing to this underutilization include:

- Limited awareness among both the public and healthcare providers about MT as a viable and time-sensitive treatment for AIS.
- Inadequate infrastructure and shortage of trained interventional specialists in most public and private hospitals.



- Economic constraints, making the procedure unaffordable for a large segment of the population.
- Geographical disparities, which hinder timely referral and transport to specialized stroke centers.

Efforts to address these challenges are underway. The PRAAN registry, a multicenter observational study, aims to collect real-world data on patient profiles, treatment systems, and outcomes to inform policy and promote MT adoption in India. Notably, the registry found that:

- MT successfully restored blood flow in 87.4% of cases.
- At 90 days post-procedure, 65.8% of patients experienced minimal or no disability.
- MT was more cost-effective compared to intravenous thrombolysis with tissue plasminogen activator (IV-tPA) alone.

These findings reinforce the urgent need for strategic interventions to scale up MT access and delivery across the country.[20,21]

8. Factors Influencing Mechanical Thrombectomy

The adoption and effectiveness of mechanical thrombectomy (MT) for acute ischemic stroke (AIS) are shaped by multiple interrelated factors, including clinical timing, healthcare infrastructure, financial barriers, and public awareness.

8.1 Time-Sensitive Nature of Treatment

The success of MT is highly dependent on timing. While the standard therapeutic window for MT is within the first 6 hours of symptom onset, landmark trials—DEFUSE 3 and DAWN—have expanded the eligibility window to 16 and even up to 24 hours in selected patients, using advanced imaging techniques to identify salvageable brain tissue.[24,25] Despite this broader window, delays in stroke recognition, diagnosis, and inter-hospital transfer frequently result in patients missing the optimal treatment period. Streamlining referral pathways and enhancing emergency response systems are therefore essential to improve timely access to MT.

8.2 Limited Awareness and Training

A significant barrier to MT adoption in India is the lack of awareness among both the general public and healthcare professionals. Stroke symptoms are often

unrecognized or misinterpreted, leading to delayed medical intervention. Additionally, many frontline physicians and emergency responders remain unaware of the time-sensitive nature of MT or lack training in stroke triage and referral protocols. National awareness campaigns and targeted clinical education programs are crucial to address this gap.

8.3 Financial Barriers

India's regional economic disparities significantly influence access to advanced medical procedures like MT. The high upfront cost of MT—including specialized equipment, imaging, and hospitalization—makes it unaffordable for many patients, especially in low-income and rural populations. Rajasthan, the largest state by area, exemplifies these challenges with its predominantly rural economy and uneven distribution of healthcare resources.

Data on income trends in Rajasthan reveal the economic vulnerability of key demographic groups: [26,27]

Individuals aged 25–29 earn an average monthly salary of ₹13,840.

Peak earnings occur between ages 50–54, with an average income of ₹33,749—still below the national average of ₹32,800.

This economic landscape further limits the affordability of MT, particularly among the working-age population most affected by stroke.

8.4 Gender and Urban-Rural Disparities

There are pronounced gender disparities in economic participation and access to healthcare, with women earning significantly less and being underrepresented in the formal workforce. In rural areas, the slower pace of urbanization and reliance on agriculture further limit access to stroke centers capable of performing MT.[12,13] This geographic inequity exacerbates treatment delays and worsens outcomes for patients outside metropolitan areas.

9. An Overview of the Data on the Economic Impact of Strokes in India

Stroke is not only a leading cause of death and disability but also a significant contributor to economic losses in India, particularly within the working-age population. The average age of stroke onset in India is approximately



50 years—a critical stage in an individual’s professional and economic life.[14,15] The impact extends beyond healthcare costs, encompassing income loss, reduced productivity, and long-term financial strain on families and caregivers.

9.1 Direct and Indirect Costs

The direct costs of stroke include hospitalization, medical treatments, diagnostic imaging, and rehabilitation. On average, the cost of hospital care for stroke patients is 23,469.68, with non-medical expenses adding approximately 5,335.26. [26] However, the financial burden extends well beyond immediate medical costs. Wage loss due to inability to work post-stroke averages 14,501, further straining households already burdened by out-of-pocket expenses.

9.2 Long-Term Productivity Loss

For an individual aged 50 earning an annual salary of 236,880, the cumulative income loss over 10 years due to post-stroke disability amounts to approximately 2,368,800. When extrapolated to the national level, productivity losses from stroke-related disability and premature mortality exceed 1.02 trillion (102,721 crores).[25,26] This figure highlights the urgent need for preventive measures, timely interventions such as mechanical thrombectomy (MT), and effective rehabilitation programs to mitigate the economic toll.

9.3 Caregiver Burden

Stroke care often requires significant time and resources from family members, with an estimated caregiver-to-patient ratio of 2:1. This not only reduces the earning potential of caregivers but also adds to the psychosocial and economic stress on families. [24] The lack of structured rehabilitation and social support programs in many regions compounds this burden.

9.4 Societal Implications

Beyond individual households, stroke imposes a heavy burden on the state and national economy by reducing workforce participation and increasing dependency on long-term care. [21,22] The economic cost of lost productivity underscores the need for integrating stroke prevention, early recognition, and access to advanced treatments like MT into public health policies.

10. Conclusion

Mechanical thrombectomy (MT) stands as a landmark advancement in the treatment of acute ischemic stroke (AIS), particularly in cases involving large vessel occlusion (LVO). Supported by robust clinical evidence, MT has consistently demonstrated the ability to improve functional outcomes, reduce long-term disability, and increase survival rates. It is now firmly established as a cornerstone of modern stroke management.

Despite its proven efficacy and cost-effectiveness, the adoption of MT in India remains dismally low. In states like Rajasthan, access is restricted by a combination of limited public awareness, inadequate infrastructure, financial barriers, and uneven geographic distribution of specialized stroke centers. These challenges persist even as the burden of stroke continues to grow—especially among individuals in their most economically productive years—exerting a profound impact on families, healthcare systems, and the national economy.

Given the staggering socioeconomic costs associated with stroke, the expansion of MT services should be viewed as both a medical and policy imperative. A multi-pronged strategy is essential: government-led initiatives to incorporate MT into national health schemes, public education campaigns to improve symptom recognition and prompt response, workforce development to increase the number of trained specialists, and financial mechanisms to subsidize treatment for underserved populations.

Widening access to mechanical thrombectomy holds the promise of transforming stroke care in India—not only by saving lives and reducing disability but also by preserving workforce productivity and alleviating the broader economic strain on society. Timely intervention today can protect both individual futures and the collective well-being of the nation.

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