Economic Viability and Cost-Effectiveness in Clinical Toxicology: An Examination of Poison Control Centres and Targeted Antidotal Treatments.

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Abstract

Introduction

Poisoning is a major global health issue. It leads to serious illness, death, and financial strain. Poison Control Centers (PCCs) help reduce healthcare costs by offering expert advice that can prevent unnecessary hospital visits. Economic evaluations, especially Cost-Benefit Analysis (CBA) and Cost-Effectiveness Analysis (CEA), assess the financial value of PCC services and the use of antidotes.

Materials and Methodology

This review examined studies from the perspectives of society, payers, and healthcare systems. Eight studies used cost-effectiveness analysis. Evaluations of primary care clinics estimated savings from avoided emergency visits. The cost-effectiveness analysis focused on comparing antidotes for paracetamol poisoning in Sri Lanka. It looked at methionine and N-acetylcystine (NAC) based on when treatment was given. Additional analyses explored the costs of deliberate self-harm cases in India and the cost-effectiveness of antivenom for snakebites.

Results and Discussion

PCCs showed important cost savings. For every dollar spent, savings ranged from $2.03 to $7.67. The Banner PCC alone saved $33 million in 2007. PCCs reduced non-hospitalized poison cases by 24% and hospitalizations by 12%. CEA indicated that PCC operations were effective strategies with considerable cost-effectiveness. For paracetamol poisoning, methionine was the most economical option within 10 hours of ingestion, while NAC became cost-effective later. The median cost for DSH hospitalization was 13,690 rupees, which increased for pesticides cases and ICU needs. AV for snakebites was very cost-effective, costing only $1,253 per death avoided.

Conclusion

PCCs provide valuable economic benefits by preventing unnecessary healthcare use. Using economic models in clinical policy helps ensure efficient use of antidotes and supports public funding, pesticide regulation, and effective poison management.

Keywords:

Poison control centers; Cost-benefit analysis; Cost-effectiveness; Antidotes; N-acetylcysteine;

Methionine; Deliberate self-harm; Antivenom; DALYs

Introduction

Poison exposures are a major global public health issue. They significantly contribute to illness, death, and financial strain [1,2]. In the United States, treating human poison exposures costs at least $8 billion each year [2]. Incidence rates are often high in low- and middle-income countries, particularly for deliberate self-harm. Patients, families, and healthcare systems are all severely impacted financially by these circumstances. Understanding the economic burden of poisoning is crucial for effective policy reforms, as these countries account for around 79% of all suicides worldwide [1].

With limited resources and shrinking healthcare budgets, economic evaluations are essential for decision-makers. They help assess the efficiency and sustainability of health interventions [2,3]. This review combines findings from studies in two main areas of economic evaluation within clinical toxicology. These areas include the overall financial benefits provided by Poison Control Centres (PCCs) and the cost-effectiveness of specific antidotal treatments for acute paracetamol poisoning, such as paracetamol overdose, snakebite envenomation.

PCCs, certified by organizations like the American Association of Poison Control Centres (AAPCC), play an important role. They offer advice and information to the public and healthcare professional to prevent and reduce harm from poison exposure. By quickly assessing the severity of cases, PCC staff often manage patients at home with follow up care. This approach helps avoid unnecessary costs associated with emergency healthcare services, including visits to emergency departments (EDs), urgent care centres, and doctor's offices [4].

The evidence shows that investing in PCCs is a sensible public health policy. This perspective often contrasts with the current trend of cutting funding of these centres [3]. Additionally, certain poisonings, such as acute paracetamol overdose in Sri Lanka and snakebite envenomation worldwide, need local cost-effectiveness studies. These studies help determine the best use of resources, especially for costly antidotal treatments like N-acetylcystine (NAC) and antivenom (AV) [5,6].

Materials and Methodology

The study employed a number of economic evaluation techniques, with a primary emphasis on cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA). It frequently used decision analysis modelling or historical data analysis [2,3]. From a variety of perspectives, including society, the healthcare system, and the payer (government or insurance), the studies aimed to compile and appraise economic estimates [3].

Study Design and Economic Evaluation Types

In a systematic economic evaluation, cost-effectiveness analysis (CEA) was used in one study and cost-benefit analysis (CBA) in eight [3]. CBA quantifies the additional expenses incurred in the absence of Patient Care Coordinators (PCCs) and measures results in monetary terms. This includes needless expenses from hospital stays, ER visits, and consultations. CEA quantifies results in natural units, such as successful outcomes or deaths prevented [3]. The CEA for snakebites specifically focused on Disability-Adjusted Life Years (DALY) avoided and deaths

avoided as primary outcomes [6]. When interventions outcomes were similar, Cost-Minimization Analysis (CMA) was appropriate. This was the case when comparing antidotes, such as NAC versus methionine, when the risk of mortality was zero [5].

Decision tree models were used to analyze the cost-effectiveness of antidotes for acute paracetamol poisoning. They compare NAC and methionine based when the patient ingested the drug, specifically within 10 hours and 10 to 24 hours. The main outcome of this modelling was death resulting from liver damage, indicated by ALT or AST levels greater than 1000 U/L [5]. Retrospective cost analyses were conducted to find the direct cost of hospitalization for patients with deliberate self-harm in India [1].

Populations and Settings

Populations studied varied based on the focus of the economic evaluation:

1. Poison Control Centers (PCCs): Studies typically targeted the residents of the service area. This includes individuals of all ages who used or might use the service [3]. Specifically, the studies looked at caller receiving home management after non-toxic exposures, [3,4,7] and patient presenting with common poison exposure like acetaminophen, tricyclic antidepressants, household cleaners, and cough or cold preparations [2].

2. Specific Interventions:
    - Acute Paracetamol Poisoning: The analysis focused on patients admitted to the National Hospital of Sri Lanka (NHSL), mainly dealing with those suffering from acute paracetamol poisoning with suicidal intent [5].
    - Deliberate Self-Harm (DSH): A retrospective study took place in a tertiary care hospital in South India involving adult patients admitted with DSH diagnosis [1].
    - Snakebite Envenoming: Systematic reviews examined studies modelling total case in the country or patients treated in hospitals located in endemic areas, assessing the provision of antivenom (AV) [6].

Cost and Data Acquisition

Cost measured included direct costs related to treatment, such as facility, fees, physician fees, hospitalization, drug treatment, and hours worked [2,5]. Some studies included non-medical direct costs, like ambulance or emergency medical services [3]. Only two economic evaluations reviewed by Galvao et al. included indirect costs related to lost productivity or earnings lost due to death [3,8].

For PCC cost savings calculations, unnecessary costs avoided were estimated through telephone surveys of callers managed at home, along with surveys of emergency departments and hospital charge databases to estimate billing for conservative management of asymptomatic patients [3,4].

For DSH studies in India, direct costs covered professional fees, bed and nursing charges, investigations, and oxygen costs, sourced from the hospital electronic database [1].

For paracetamol antidotes in Sri Lanka, costs were calculated based on drug prices (NAC/methionine), hospital stay, and hours worked. Effectiveness data came from systematic reviews about the probabilities of developing hepatotoxicity and death [5].

Result and Discussion

Economic Impact of Poison Control Centers (PCCs)

PCCs show strong economic value and high returns on investment in many developed countries [3]. They save money mainly by managing a large number of patients at home, especially those with non-toxic exposure. This approach prevents expensive and unnecessary visit to emergency department (EDs) or other healthcare facilities [4,7,9].

Averted Healthcare Utilization and Cost Savings: Research shows that without PCCs, many people would seek unnecessary medical care [1,4,7].

- The Banner Poison Control Centre (BPCC) in Central Arizona managed 41,262 human exposures at home in 2007, preventing 28,883 unnecessary ED visit (estimating that 70% would have sought care) [7].
- The BPCC stopped a median of **$33 million** (ranging from $18 million to $45 million) in unnecessary healthcare cost in 2007 [4].
- For every dollar of state funding the BPCC received in 2007 ($925,000), it prevented about **$36** in unnecessary healthcare costs. This estimate may be high since it only includes state funding and not the total operating budget, which typically has federal, local, and private contributions [3,4].
- The overall cost-benefit ratios (CBRs) for PCCs from various US studies fall between 2.03 and 7.67. This means that for every dollar spent on the PCC, up to $7.67 is saved in healthcare costs [3].
- A 1997 analysis found that PCCs reduced the number of medically treated non-hospitalized poison cases by 350,000 (24%) and hospitalization by 40,000 (12%) nationally in 1992 [8].
- Each public call to PCC for assistance saved **$175** in other medical expenses [8].
- A study in Singapore showed that for every dollar spent on the Drug and Poison Information Centre (DPIC), its work saved about $2.76 in related healthcare costs. Over two years, the DPIC's total savings was $1,401,740 against an operating cost of $507,922, resulting in net savings of $893,818 [9].

Cost-Effectiveness Metrics:

Cost-effectiveness analyses with clinical outcomes reveal that PCCs are often the best choice, demonstrating increased effectiveness along with decreased costs [2].

- For treating poison exposure, the cost-effectiveness analysis showed minimum incremental cost-effectiveness ratios (ICER) of -$12,000 for morbidity and -$56,000 for mortality, indicating that PCCs saved at least these amounts for each successful outcome [2,3].
- The average cost per patient treated with PCC services was nearly half of the cost without PCC services across four common poison cases (acetaminophen overdose, tricyclic antidepressant overdose, cleaning substance exposure, and cough/cold preparations overdose [2].
- Without a PCC, the incremental cost-effectiveness ratio for cough or cold preparation overdose mortality was -$250,000, representing average savings of $250,000 for each additional successful outcome by an RPCC [2].

Caller Behaviour and Facility Use:

A survey of San Francisco Bay Area PCC callers showed that 79% (464 of 589) would have reached out to their local emergency healthcare system if the PCC had not been available. The most common alternatives mentioned were calling an ED (29%) or contacting a physician (26%). In addition, those who were publicly insured or uninsured were more likely to go directly to an

emergency department or call 911 (35%) compared to those with private insurance (20%) [7]. This highlights the important role of PCCs in reducing pressure on already crowded emergency departments, especially for vulnerable groups [4,7].

Economic Evaluation of Specific Poisoning Management

While PCCs focus on preventing unnecessary use, other economic studies look at the most cost-effective clinical treatment once acute poisoning happens, especially in settings with limited resources.

1. **Cost-Effectiveness of Antidotes for Acute Paracetamol Poisoning (Sri Lanka):** Acute paracetamol poisoning is becoming a more common and costly issue in Sri Lanka. The most expensive part of treatment is often the antidote therapy [5].

- Treatment within 10 hours: For patients treated within 10 hours of acute ingestion, the chance of death after using either antidote (NAC or methionine) was zero, according to available evidence. In this case, Cost Minimization Analysis was suitable, and methionine was found to be the least expensive antidote. The cost difference showed NAC treatment to be significantly higher, with an incremental cost of LKR 11,588,680 for 1,000 hypothetical patients [5].
- Treatment within 10 to 24 hours: For patients who arrived 10 to 24 hours after poisoning, NAC was found to be more effective than methionine. The ICER for NAC was LKR 316,182 per life saved. This ICER was much lower than the set treatment threshold of LKR 1,537,120 for each death prevented (based on expected productive life gained and average contribution to GDP), indicating that using NAC is highly cost-effective for this group of patients [5].
- Cost Details: Treating 60 kg patient with NAC without developing hepatoxicity cost 15,038 rupees: this increased to 34,329 rupees if hepatotoxicity occurred. The total cost for the methionine option was 2,839 rupees without hepatoxicity and 22,481 rupees with hepatoxicity [5].

2. **Cost of Deliberate Self-Harm (DSH) Management in (South India):** DSH carries heavy economic burden. A Study in South India looked back at 107 patients and found that median cost of admission was 13,690 rupees (USD 195.57) [1].

- Pesticide Poisoning: The most common poison consumed was pesticides at 35.5% followed by tablet overdose at 31.8%. Pesticide use raised direct care costs by 67% compared to cases of non-pesticides poisoning [1].
- Critical Care Impact: The demand for intensive care resources sharply raised costs. Admission to the Intensive Care Unit (ICU) increased costs by 6.65 times, ventilator support raised costs by 7.33 times, and the development of Ventilator-Associated Pneumonia (VAP) boosted costs by 11.65 times [1].
- These results indicate that limiting free access to highly hazardous pesticides, which lead to more intensive care and mechanical ventilation, could reduce the economic burden [1].

3. **Economic Evaluation of Antivenom for Snakebites:**
Snakebite envenoming is a neglected disease that impacts poor populations. Researchers have examined it using cost-effectiveness methods, mainly focusing on antivenom (AV) administration [6].

- The economic evaluation showed that Av treatment is very cost-effective [6].
- The Cost-Effectiveness Ratio (CER) for AV treatment was USD 1253 (2017 PPP constant value) for each death avoided [6].
- The cost per DALY avoided was USD 51, with values ranging from USD 18 to USD 161 across different studies [6].

- Standardizing interdisciplinary care management protocols improved cost-effectiveness by allowing for better use of resources. For instance, standardized treatment cost USD 2178 per successful outcome, while non-standardized treatment cost USD 4121 [6].

Discussion and Methodological Limitations

The evidence strongly shows that poison control services are cost-effective and provide significant financial benefits when antidotes are used correctly [3,6].

In developed countries, poison control centers (PCCs) are effective and help lower costs. The money saved from preventing unnecessary emergency department visits greatly outweighs the operational costs of the PCCs [3,7]. However, a constant issue is that major payers for poisoning treatment, such as the federal government and third-party insurers, typically save the most money. The majority of the financial burden, however is frequently borne by other organizations, such as state governments and hospitals [8].

In developing nations, the emphasis is on managing costly treatments in accordance with stringent clinical guidelines. The importance of timing is highlighted by the significant cost difference between methionine and NAC in cases of paracetamol poisoning, where methionine must be administered within 10 hours (CMA strategy) and NAC between 10 and 24 hours (CEA strategy, which is valid due to an ICER below the threshold).This approach of tailoring antidote treatment based on economic assessments and clinical guidelines gives policy makers a path to use economic evaluations to enhance decision-making and potentially cut total costs for common poisonings in half [5].

Methodological Constraints: Several limitations exist in the primary studies reviewed, which may mean that the reported savings figures are conservative.

1. Cost Underestimation: Many PCC studies used conservative cost estimates. For example, the cost calculations often left out charges for potential interventions like basic lab studies, radiology, cardiac monitoring, intravenous fluids, or prehospital treatment and transportation, such as ambulance costs [2,4,7,8]. BPCC's most conservative estimate assumed Level 4 physician billing, but most physicians stated they would generate a Level 5 bill. This suggests the actual savings were likely much higher [4].
2. Reliance on Survey Data: PCC effectiveness estimates often depended on retrospective telephone surveys asking callers what they would have done without the PCC. This introduced the possibility of recall bias. Additionally, some CEA models relied on expert panel opinions for clinical outcome probabilities due to a lack of empirical data [4].
3. Exclusion of Intangible Costs: Most studies did not not consider intangible costs, such as patient and family anxiety stress, or lost wages due to treatment or death. This means the true societal benefits are probably underestimated [2,3,9].
4. Data Quality in Treatment Studies: The effectiveness data for paracetamol antidotes came from a systematic reviews and meta-analysis, where many of the included trials were not of high quality (Grades D or worse). A randomized controlled trial directly comparing NAC and methionine would provide much better effectiveness data [5]. Similarly, snakebite evaluations often lacked solid uncertainty and incremental analyses [6].

Despite these methodological issues, the evidence strongly supports the economic viability of PCCs in improving healthcare efficiency and reducing costs [2,3,7]

Conclusion

Poison control centers (PCCs) are cost-effective. They offer favourable cost-effectiveness and cost-benefit ratios from the viewpoints of the healthcare system, payers, and society [2,3]. By managing exposures at home, their services significantly reduce unnecessary use of emergency

healthcare resources. This leads to substantial savings that often cover their operational costs [3,4,7].

Clinical toxicology economic considerations are not limited to PCC operations. Additionally, they concentrate on improving therapy regimens. For instance, economic analysis recommends utilizing methionine, a less expensive antidote, for patients who arrive during the first 10 hours in cases of acute paracetamol poisoning in Sri Lanka. This is due to the equal chances of recovery. For patients who come in 10 to 24 hours later, the recommendation is to use N-acetylcystine (NAC), which is more expensive but more effective [5]. Likewise, antivenom (AV) for snakebites shows high cost-effectiveness for each death or disability-adjustedlife year (DALY) avoided. This supports its prioritized use in areas where snakebites are common [6].

Additionally, deliberate self-harm (DSH) by poisoning, especially with pesticides, poses a huge economic burden in developing countries. The costs can increase sharply when intensive care is needed [1].

Investing in existing PCCs expanding their services, and incorporating cost-effectiveness data into clinical guidelines for antidote use is a sensible public health approach. This can improve health outcomes and ensure efficient use of limited resources [3,5]. Further research should look to measure intangible costs and evaluate these interventions in a wider range of less developed countries to confirm that the findings are universally applicable [3].

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