Assessing the Economic Feasibility of Needle-Retractable Safety Syringes (NRSS) Adoption in Indian Healthcare Facilities

Girish Kumar Kuppireddy[1], Dr. Kamineni Saradhi[2]

[1]*Research Scholar, School of Commerce & Management, Mohan Babu University, Tirupati, PIN-517102, Andhra Pradesh, India. Email: 22104R020002@mbu.asia*
[2]*Registrar, School of Commerce & Management, Mohan Babu University, Tirupati, PIN-517102, Andhra Pradesh, India. Email: saradhi.kamineni@gmail.com*

KEYWORDS
blood-borne infections, economic feasibility, (HBV) hepatitis B virus, (HCV) hepatitis C virus, human immunodeficiency virus (HIV), needle-stick injuries, price analysis, reuse prevention

ABSTRACT
Description: Globally, sixteen billion injections are given each year, 95.00% of which are for medicinal purposes. This global injection burden is accounted for by India between 24.5% and 31.0%, and alarmingly, over 62.50% of these injections are performed improperly or are repeated.
Objectives: The purpose of this study is to assess the increased costs incurred by transitioning from traditional disposable syringes to Needle-Retractable Safety Syringes (NRSS) for beneficial usage in India.
Methods: Utilizing a decision tree model, we evaluated the occurrence of needle-stick injuries and syringe reuse among healthcare personnel and patients. We calculated the lifetime costs associated with HIV - Human Immunodeficiency Virus, HBV - Hepatitis B Virus, and HCV - Hepatitis C Virus infections using three Markov models.
Results: NRSS offer substantial benefits by reducing needle-stick injuries and preventing blood-borne infections. Among the options analyzed, Reuse Prevention (RUP) syringes emerged as the most cost-effective choice. In contrast, Single-Use Prevention (SIP) and NRSS syringes are currently not deemed cost-effective at their prevailing prices. We recommend prioritizing RUP syringes and exploring strategies to make them more affordable for broader accessibility.
Conclusion: Our analysis suggests that, in the Indian context, RUP syringes present an economically viable solution. However, SIP and NRSS syringes do not currently offer cost-effectiveness. To enhance the cost-effectiveness of NRSS, concerted efforts should be directed towards reducing their price.
Abbreviations: NRSS, Needle-Retractable Safety Syringes; RUP, Reuse Prevention; SIP, Single-Use Prevention; NSI, Needle Stick Injuries; BBI, Blood-borne Infections; QOL, Quality-of-life; BCC, Behavior Change Communication.

1. Background

An unbelievable 16 billion injections are given annually on a global basis, with a significant 94.50% used for therapeutic purposes. With a contribution of between 24.5% and 29.5% of the total world injection volume, India plays a crucial role in this scenario. Alarmingly, it has been discovered that over 65.5% of these injections were given in a risky or frequently needless way. The term "unsafe injection practises" refers to a variety of problems, such as the unsafe practise of recapping needles, the misuse of injections when oral drugs would be adequate, and the reuse of syringes and needles. For a number of compelling reasons, it is crucial to address these dangerous practises in healthcare.

They are first and foremost in charge of the broad spread of blood-borne illnesses (BBIs) among patients. In poor nations, improper medicinal injections are responsible for about 32.55% of new instances of hepatitis B virus (HBV) infections and 41.20% of new cases of hepatitis C virus (HCV), totaling 1.99 million new infections. Furthermore, 9.01% of new infections of human immunodeficiency virus (HIV) in South Asia are brought on by hazardous injection practises. Second, needle-stick injuries (NSIs) put healthcare professionals (HCPs) at risk for BBIs. Thirdly, improper treatment of sharps waste places communities and waste handlers at serious danger.

Syringe reuse is said to occur at a rate of 4.9% in the Indian setting, while NSIs are said to occur at a rate of 0.055 per 1000 delivered injections. There is a significant danger of BBI transmission via the reuse of syringes, passing contaminated ones from sick to healthy patients, and NSIs involving medical staff after using a needle on an infected patient. It's important to note that reuse of syringes, as opposed to NSIs, greatly contributes to BBIs brought on by hazardous injection practises in impoverished nations. It's important to note, however, that many research from wealthy nations have not considered BBIs brought on by injection reuse, identifying this as a restriction.

In India, viral hepatitis continues to be a serious public health issue. Hepatitis B surface antigen endemicity in the nation is classified as "intermediate to high," with an estimated 39.90 million people carrying a chronic HBV infection, or 10.90% of the world's burden. With notable geographical differences, the incidence of chronic Hepatitis B and C infections in India is between 2-5% and less than 1.5%, respectively. India is the third-highest country in the world in terms of prevalence among adults 16 to 50 years old for the human immunodeficiency virus. The cost of treating HBV, HCV, and HIV places a significant financial strain on the healthcare system, with household out-of-pocket expenses (OOPEs) accounting for 70% of overall healthcare costs.

Ref. Fig. Needle-Retractable Safety Syringes (NRSS)

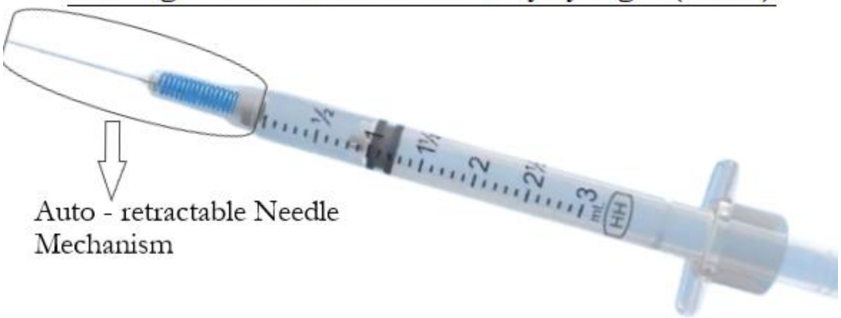

Image Source: www.hervikhealthcare.com

By 2020, safety-engineered Injectable devices should be the norm, according to the World Health Organisation (WHO). The purpose of needle-retractable safety syringes (NRSS), which have cutting-edge safety features, is to shield healthcare personnel from unintentional NSIs and reuse. Although auto-disable (AD) syringes were adopted by the Government of India (GoI) for immunisation reasons in 2008, their usage is not required in the therapeutic sector, which accounts for the bulk of injection use.

2. Methodology

2.1. Model Summary

We compared the potential of needle-retractable safety syringes (NRSS) for therapeutic use in India to the current usage of disposable syringes in this study. Our study used a societal perspective on a lifetime study horizon, concentrating on direct costs incurred by persons afflicted by blood-borne illnesses (BBIs). In our analysis, we did not account for productivity losses. Needlestick injuries (NSIs) among healthcare personnel and the prevalence of syringe reuse among patients were among the direct effects of hazardous injection practises considered.

For this investigation, we created a two-part dynamic transition model. The initial portion of the model used a decision tree to determine the number of NSIs and instances of syringe reuse among healthcare personnel and patients, respectively (see Figure 1). Over a 20-year period, from 2023 to 2043, we predicted the yearly number of BBIs in each of the Needle-retractable safety syringes (NRSS) choices and the control scenario.

In order to calculate the lifetime costs and Quality-Adjusted Life Years (QALYs) for patients who contracted the hepatitis B virus (HBV), hepatitis C virus (HCV), or the human immunodeficiency virus (HIV), respectively, in either of the study scenarios, the second part of the model included three different Markov models (see Figures 2 and 3). It's crucial to remember that the three Markov models used in this research have previously been validated and are supported by published research [23, 27]. The Markov and choice models were both predicated on an annual cycle.

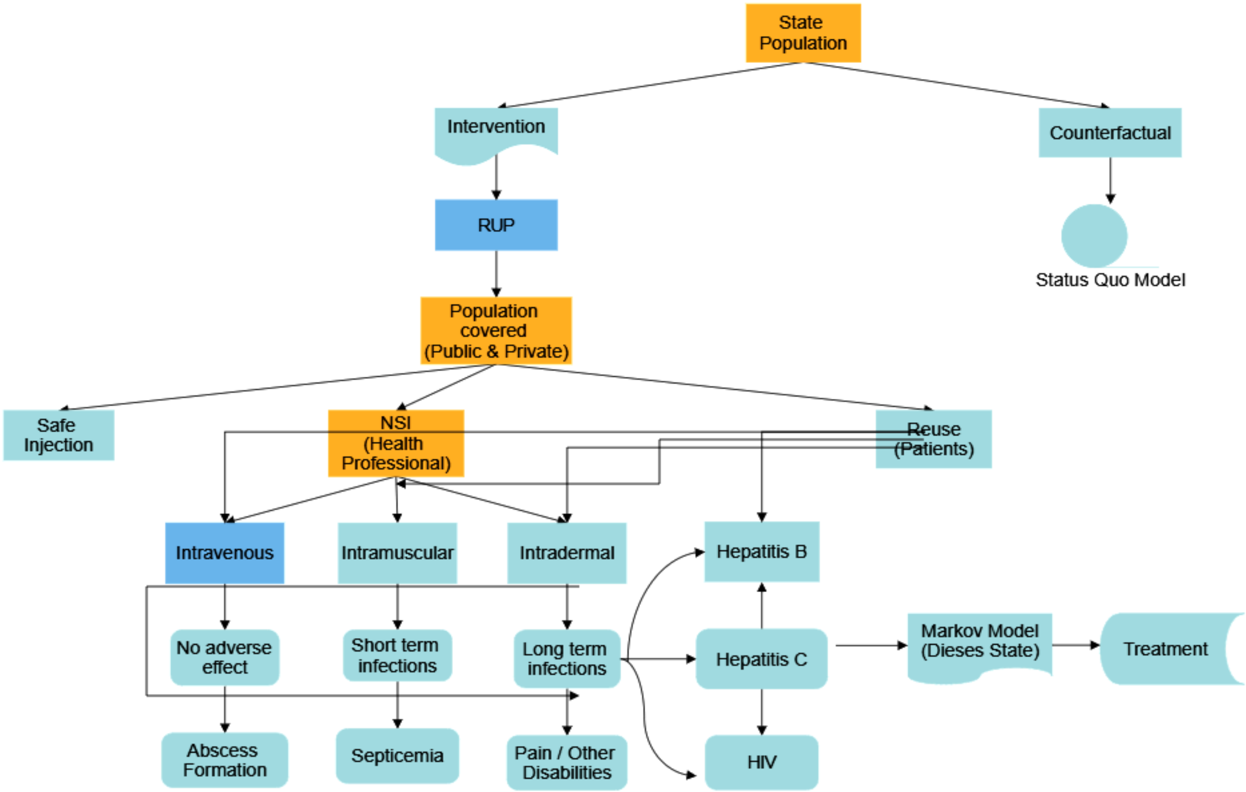

Figure. 1: Decision Tree for The economic effectiveness of safety engineered Syringes
Source: Author's own creation

2.2. The cost of unsafe injections

[This reference is sourced from the publication titled "The cost of unsafe injections," co-authored by M.A. Miller1 and E. Pisani2. It was published by the World Health Organization in 1999 within the pages of the Bulletin of the World Health Organization, volume 77 (10).]

Estimations of the worldwide yearly occurrence, fatalities, years of life lost, and economic repercussions stemming from unsafe injection practices related to hepatitis B, hepatitis C, and human immunodeficiency virus (HIV) infections, utilizing the most favorable assumptions aimed at minimizing disease impact and associated expenses.

Table: 1:

Details	Hepatitis B	Hepatitis C	HIV	Total
Yearly occurrence of infections resulting from unsafe injections (in millions).	8.21	2.30	0.101	10.601
Projected fatalities in the future (in millions).	1.01	0.20	0.10	1.302
The quantity of years of life lost (in millions).	19.70	3.60	2.71	26.01
The total medical expenses incurred due to the disease (in millions of US dollars).	327.00	59.00	149.00	535.00

1. [a] Annual death rates assumed to be at their lowest levels due to minimal infection rates.
2. [b] Anticipated future fatalities attributed to hepatitis, calculated based on the assumption that 70% to 80% of infections progress to a carrier state for hepatitis (except in countries within the former socialist economies of Europe and Eastern Mediterranean countries, where carrier rates per infection were assumed to be 10% due to later age of acquisition). The number of deaths was estimated considering mortality rates of 20%, 10%, and 100% for carrier states associated with hepatitis B & C, and HIV, respectively.
3. [c] The count of years of life lost derived from the current life expectancy in each respective country. The average age at death was presumed to be 45 years for hepatitis B & C and 30 years for HIV.

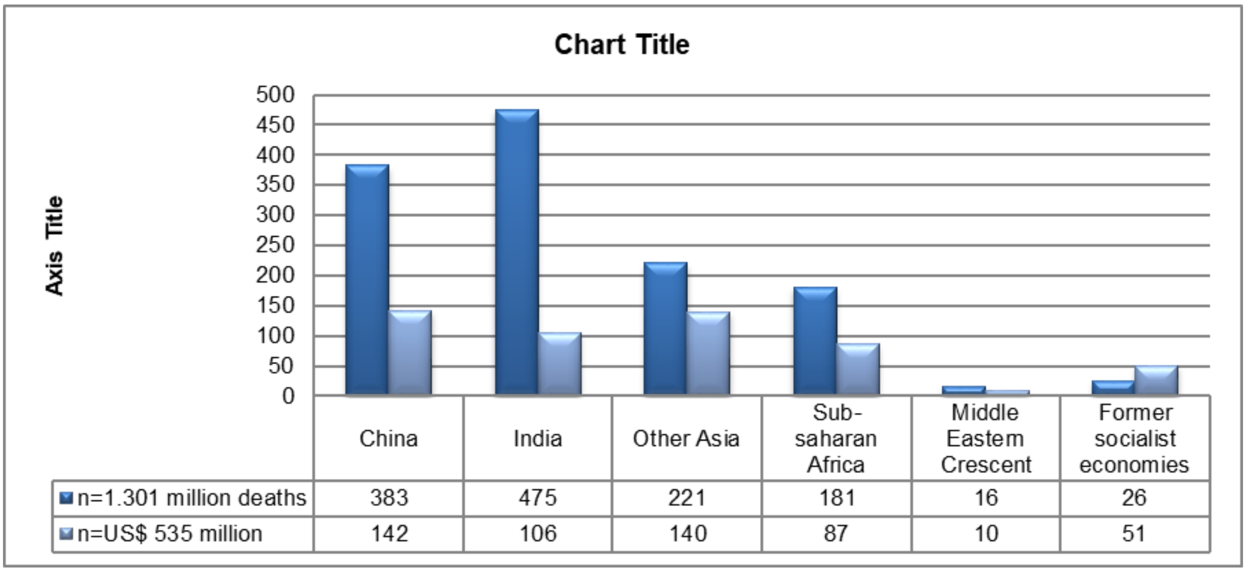

Fig. : A) Precise calculations of mortality rates, and B) Disease-related expenses resulting from unsafe injections

A) Accurate estimations of the mortality linked to HIV, hepatitis B, and hepatitis C infections resulting from unsafe injections. Hepatitis B cross-infections were thought to happen in impoverished countries from infancy, escalating to a chronic carrier condition in 70% of people with a 20% death rate. It was believed that cross-infections with HIV would always result in death.

B) The cost of managing hepatitis (ranging from US$ 90 to US$ 490) and HIV (ranging from US$ 990 to US$ 9100) in each region was determined based on countries with similar economic profiles.

2.3. Intervention Description

In the intervention scenario, we examined three types of Needle-retractable safety syringes (NRSS), each equipped with distinct safety features.

Option 1 involved the introduction of a re-use prevention syringes (RUPs), which prevents syringe reuse through mechanisms like a breakable plunger or a locking metal clip.

Option 2 concentrated on using a syringe with a plastic shield that automatically covers the needle after use and prevents sharp injuries. The purpose of this design was to protect healthcare workers and trash handlers from needlestick injuries.

Option 3 provided a twofold advantage by avoiding both syringe reuse and needlestick injuries by combining elements from RUP and SIP. Our attention was specifically on the combo that included an automated safety function because manual-driven versions still posed certain concerns.

We assumed that RUP and RUP + SIP syringes would entirely eliminate syringe reuse, while the reuse rate for SIP syringes remained unchanged. Additionally, integrated training programs were included in each option, covering safe injection practices, proper syringe use, waste management, and patient behavior change communication. However, we did not include any additional advantages resulting from the training or behaviour change communication in our study. We only took into account the expenditures related to these training activities.

2.4. Pricing

In the intervention arm, we factored in various pricing components, including the procurement costs for the respective Needle-retractable safety syringes (NRSS), expenses associated with providing pre-exposure prophylaxis for hepatitis B virus (HBV) and human immunodeficiency virus (HIV), treatment costs for HBV, hepatitis C virus (HCV), and HIV, as well as the costs for training on safe injection practices (which encompassed the use of Needle-retractable safety syringes or NRSS) and safe waste-management practices.

Moreover, we considered prices related to behavior change communication (BCC) campaigns and the management of sharp waste. The unit prices for Needle-retractable safety syringes (NRSS) were derived from the World Health Organization (WHO) and then converted to the local currency (Indian Rupee, INR) using applicable conversion rates. For hepatitis and HIV patient care, we estimated treatment prices based on the utilization patterns across different healthcare delivery levels.

National surveys and reports were utilised to compile data on healthcare-seeking behaviours, including the sector, degree of treatment, and setting used. From numerous research and databases, we gathered information on the costs of the healthcare system and out-of-pocket expenses (OOPE) for care in the public and private sectors. The cost of HCV therapy, which includes diagnostics and antivirals, was determined by the state's Free HCV therapy Scheme. We obtained the cost of antiretroviral medication for HIV treatment from a local research. Discussions with programme managers for the health system helped to set the cost for training, BCC efforts, and waste management. Contract rates from outsourced service providers were also considered. We used the proper gross domestic product (GDP) price deflators to update price estimates from earlier research to account for inflation.

In the counterfactual scenario, pricing resembled that of the intervention, except for the cost of disposable syringes, which was based on data from the WHO report. Furthermore, the pricing of training and Information, Education, and Communication (IEC) was not considered in the counterfactual scenario.

2.5. Modeling Health Benefits

Initially, we estimated the yearly injection volume by considering the frequency of injections per individual per year across various healthcare sectors, levels of care, and categories of care. It's important to note that our analysis specifically centered on therapeutic care and did not encompass preventive care. To further refine our calculations, we categorized the injection volume based on the method of administration (intravenous, intramuscular, intradermal, and subcutaneous) owing to the differing risks associated with the transmission of blood-borne infections.

In order to gather information on a variety of topics, including the healthcare workforce, morbidity rates, patient behaviours regarding seeking medical attention, patterns of healthcare utilisation, injection frequency, administration routes, healthcare professional-managed treatments, risks related to needle-stick injuries, rates of syringe reuse, and the prevalence of the viruses hepatitis B (HBV), the virus that causes hepatitis C (HCV), and HIV, we conducted a thorough review of the existing literature.

We developed a wide range of uncertainty assumptions for transmission coefficients due to the dearth of trustworthy data on HIV transmission risk in the Indian setting. It is notable that the risk of HIV transmission has been linked to the prevalence of sexually transmitted diseases. Please see Table 1 in the supplemental appendix for further information on the parameter values and their associated sources.

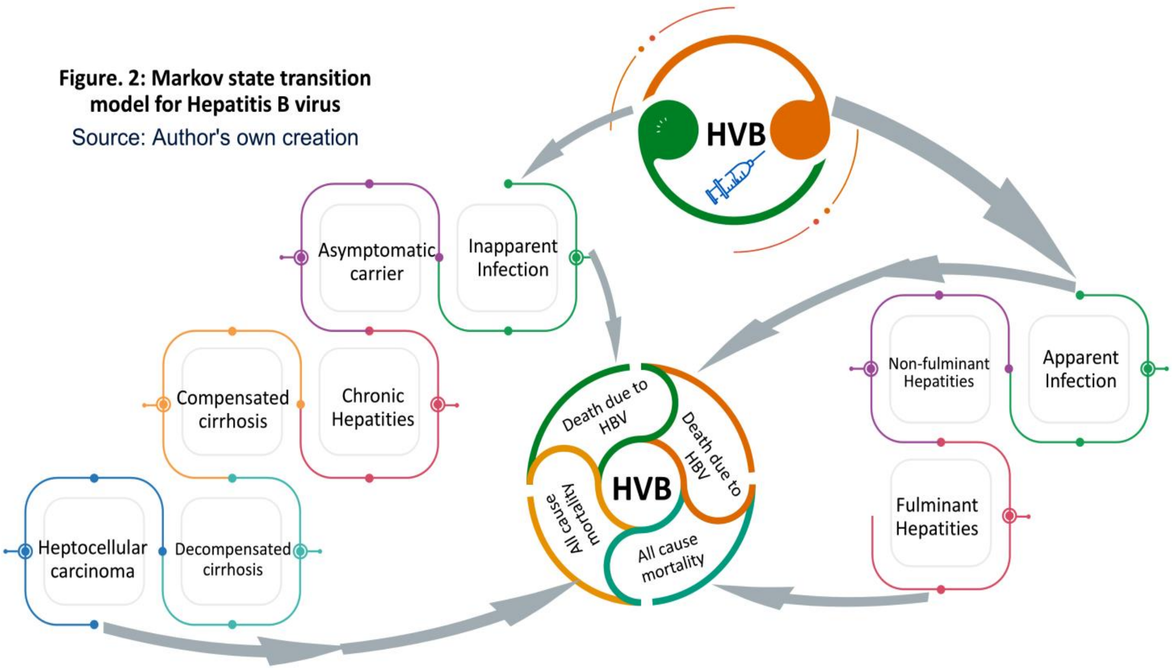

Figure. 2: Markov state transition model for Hepatitis B virus
Source: Author's own creation

2.6. Comparison of the Efficiency of Various Needle-Retractable Safety Syringes (NRSS) with Non-Safety Disposable Syringes in Reducing Needle-Stick Injuries (NSIs) Among Healthcare Professionals and Preventing Syringe Reuse in Patients

We performed a systematic review to compare different Needle-Retractable Safety Syringes (NRSS) to conventional disposable syringes without safety features in order to assess how well they prevented needle-stick injuries (NSIs) among medical professionals and discouraged patient syringe reuse. Our review included both randomised controlled trials (RCTs) and non-randomized studies (NRS), including cohort research, case-control research, time-series data analyses, before-and-after trials, and surveys with quantitative data.

Conference abstracts, letters to the editor, qualitative research, reviews, incident series, and individual reports of cases were all purposefully left out. Additionally, studies that examined implanted needles, wings steel needles, suture needles, catheters, cannulas, and safety devices for blood collection were disregarded. Studies that looked at the intervention and a comparator with safety characteristics were not taken into consideration. Furthermore, research that used recollection techniques to calculate the frequency of NSIs were excluded from our study. Only studies that evaluated NSIs using precise measures qualified for inclusion in our evaluation.

The primary objective of this review was to compile evidence regarding the effectiveness of Needle-Retractable Safety Syringes (NRSS) in reducing NSIs among healthcare workers. This evidence would, in turn, inform our comparative analysis between various types of Needle-Retractable Safety Syringes (NRSS) and conventional disposable syringes devoid of safety features.

2.7. Transmission of Blood-Borne Infections (BBIs)

Five important elements can affect the spread of blood-borne illnesses (BBIs) from an infected source to an uninfected person. First and foremost, it depends on how common the particular blood-borne pathogen is in the population where the illness first appears. The chance of the viral bloodborne pathogen being present in the syringe and the depth of the needle puncture during a needle-stick injury (NSI) are what determine the probability of transmission. The third factor involves the probability of specific practices, which encompasses the rates of NSIs and the reuse of syringes. The fourth factor is the likelihood of infection transmission, which is indicated by transmission coefficients that assess the probability of transmission per exposure. Lastly, the fifth factor is the probability of susceptibility, which gauges an individual's vulnerability to infection based on factors like vaccination status, particularly applicable for hepatitis B (HBV).

We calculated the number of secondary BBIs in addition to predicting BBI transmission by NSIs and syringe reuse. When a main patient spreads the illness to their frequent sexual partner through heterosexual contact, secondary infections result. We used the common Weinstein equation to calculate the number of secondary BBIs for HIV and HBV. This formula accounts for a variety of variables, such as the prevalence of BBIs in the partner group, the kind of sexual activity, the usage of condoms and their efficacy, and the average number of sexual partners per person.

The estimation of new infections resulting from NSIs and syringe reuse was projected over a 20-year period, involving 20 cycles in the model. The lifetime effects were then calculated using this projection in terms of life years and quality-adjusted life years (QALYs).

2.8. Quality-of-Life Assessment

From the international literature already in existence, we obtained Quality-of-Life (QOL) ratings correlated with various health problems linked to the three illnesses, namely HBV, HCV, and HIV. It is crucial to stress that the QOL ratings are not directly impacted by the syringes used. The effectiveness of using various Needle-Retractable Safety Syringes (NRSS) in avoiding Needle-Stick Injuries (NSIs) and cases of syringe reuse, however, does vary. In turn, compared to the use of standard disposable syringes, this leads to a decrease in the frequency of blood-borne illnesses (BBIs) that people encounter.

We assigned QOL scores to the disease states associated with the three BBIs (hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV), in order to estimate the increase in Quality-Adjusted Life Years (QALYs) associated with each Needle-Retractable Safety Syringe (NRSS) scenario. The difference in QALYs between the compared syringe options was determined by considering the number of BBIs in each scenario resulting from NSIs and syringe reuse. Through the reduction in BBIs achieved by utilizing safety-engineered syringes, it is anticipated that individuals will enjoy enhanced health outcomes and a higher overall

QALY score.

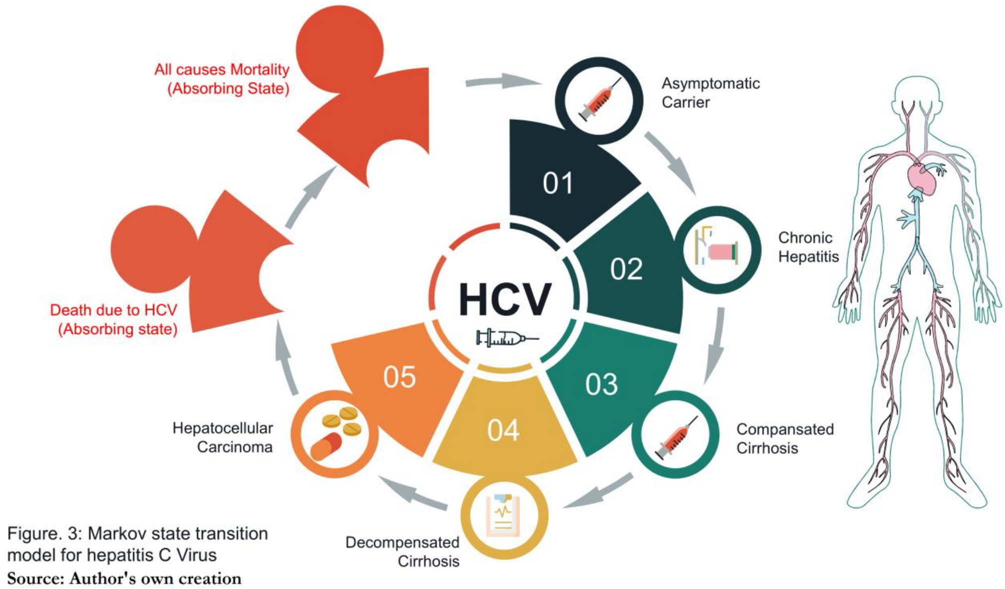

Figure. 3: Markov state transition model for hepatitis C Virus
Source: Author's own creation

Table 2: lists the key variables used in the price-benefit analysis for safety-engineered syringes in Indian healthcare facilities.

Parameters	Probability Distributions in the Price-Feasibility Model	Their Base Values	Lower Limits	Upper Limits	Sources (Reference Numbers)
Morbidity Rate in India	Uniform Distribution	0.1	0.89	0.118	[97]
Proportion of Injections in Outpatient Departments (OPD) by Administration Route					
Intravenous (IV) refers to the administration route where a substance	Uniform Distribution	0.1285	0.1284	0.1286	[42]
Intramuscular (IM) refers to the administration route in which a substance	Uniform Distribution	0.4714	0.4713	0.4715	
Intradermal (ID) refers to the administration route in which a substance	Uniform Distribution	0.2857	0.2856	0.2858	
Distribution of Injections by Administration Method in Outpatient Departments (OPD)					
Intravenous (IV) refers to the administration route where a substance	Uniform Distribution	0.7667	0.7666	0.7668	
Intramuscular (IM) refers to the administration route in which a substance	Uniform Distribution	0.2167	0.2166	0.2168	
Intradermal (ID) refers to the administration route in which a substance	Uniform Distribution	0.0	0.0	0.0	
Reuse Rate					
Single-Use Syringes (Needle-Stick Injuries)	Uniform Distribution	0.05	0.0022	0.15	[7,45]
Disposable syringe	Uniform Distribution	0.051	0.0407	0.062	[10]
RUP – Reuse Prevention	Uniform Distribution	0.051	0.0407	0.062	[10]
SIP – Sharp injury Prevention	Uniform Distribution	0.0061	0.0407	0.00740	[34]
NRSS – Needle retractable safety Syringe	Uniform Distribution	0.0061	0.0407	0.00740	[34]
Incidence among individuals seeking medical care					
Hepatitis B Virus (HBV)	Uniform Distribution	0.039	0.0086	0.0414	[46,47,98]

Hepatitis C Virus (HCV)	Uniform Distribution	0.0068	0.0027	0.0078	[47,99]
Human Immunodeficiency Virus (HIV)	Uniform Distribution	0.0068	0.0034	0.0084	[47-49]
Risk of transmission: Hepatitis B Virus (HBV)					
Intravenous (IV) refers to	Beta Distribution	0.18	0.05	0.40	[100]
Intramuscular (IM) refers to	Beta Distribution	0.018	0.005	0.04	
Intradermal (ID) refers to	Beta Distribution	0.00001	0.000001	0.0001	
Risk of transmission: Hepatitis C Virus (HCV)					
Intravenous (IV) refers to	Beta Distribution	0.018	0.001	0.08	[101]
Intramuscular (IM) refers to	Beta Distribution	0.0018	0.0001	0.008	
Intradermal (ID) refers to	Beta Distribution	0.00001	0.000001	0.0001	
Risk of transmission: Human Immunodeficiency Virus (HIV)					
Intravenous (IV) refers to	Beta Distribution	0.0023	0.0001	0.0046	[102]
Intramuscular (IM) refers to	Beta Distribution	0.00023	0.00001	0.00046	
Intradermal (ID) refers to	Beta Distribution	0.0000001	0.00000001	0.000001	
Price parameters (INR)					
Per unit price of disposable syringe	Gamma Distribution	3ml – 08.00	06.00	20.00	
Per unit price of RUP syringe	Gamma Distribution	3ml – 12.00	10.00	22.00	
Per unit price of SIP syringe	Gamma Distribution	3ml – 14.00	12.00	28.00	
Per unit price of NRSS syringe	Gamma Distribution	3ml – 18.00	16.00	30.00	
Treatment Cost in the Public Healthcare Sector at the Secondary Level (in INR) – mean cost					
Hepatitis B Virus (HBV)	Gamma Distribution	1734	1212.7	2254.3	[21,32,37]
Hepatitis C Virus (HCV)	Gamma Distribution	1734	1212.7	2254.3	
Human Immunodeficiency Virus (HIV)	Gamma Distribution	25,659	17961	33356	[38]
Treatment Cost in the Public Healthcare Sector at the Tertiary Level (INR) – mean cost					
Hepatitis B Virus (HBV)	Gamma Distribution	2024	1415.70	2631.21	[21,32,37]
Hepatitis C Virus (HCV)	Gamma Distribution	2024	1415.70	2631.21	
Human Immunodeficiency Virus (HIV)	Gamma Distribution	45,810	32,067	59,552	
Average Treatment Cost in the Public Healthcare Sector at the Secondary Level for Inpatient Care (in Indian Rupees, INR)					
Hepatitis B Virus (HBV)	Gamma Distribution	7597	5316.80	9876.12	[21,32,37]
Hepatitis C Virus (HCV)	Gamma Distribution	7597	5316.80	9876.12	
Human Immunodeficiency Virus (HIV)	Gamma Distribution	995	695.40	1293.5	
Mean Treatment Cost in the Public Healthcare Sector at the Tertiary Level for Inpatient Care (in Indian Rupees, INR)					
Hepatitis B Virus (HBV)	Gamma Distribution	18,693	13,084.10	24,300.90	
Hepatitis C Virus (HCV)	Gamma Distribution	18,693	13,084.10	24,300.90	
Human Immunodeficiency Virus (HIV)	Gamma Distribution	5,592	3,915.40	7,269.60	
Average Cost of Treatment in the Private Healthcare Sector for Outpatient Care at the Secondary Level (in Indian Rupees, INR)					
Hepatitis B Virus (HBV)	Gamma Distribution	8625	6037.50	11,212.50	[21,32,37]
Hepatitis C Virus (HCV)	Gamma Distribution	8625	6037.50	11,212.50	
Human Immunodeficiency Virus (HIV)	Gamma Distribution	0.00	0.00	0.00	
Average Cost of Treatment in the Private Healthcare Sector for Outpatient Care at the Tertiary Level (in Indian Rupees, INR)					
Hepatitis B Virus (HBV)	Gamma Distribution	1400	981.0	1820	[21,32,37]
Hepatitis C Virus (HCV)	Gamma Distribution	1400	981.0	1820	
Human Immunodeficiency Virus (HIV)	Gamma Distribution	1358	951.61	1765.4	
Average Cost of Treatment in the Private Healthcare Sector for Inpatient Care (in Indian Rupees, INR)					
Hepatitis B Virus (HBV)	Gamma Distribution	26,774	18,742.81	34.806.21	[22,33,38]
Hepatitis C Virus (HCV)	Gamma Distribution	26,774	18,742.81	34.806.21	

Human Immunodeficiency Virus (HIV)	Gamma Distribution	8000	5601	10,400	
Parameters related to Feasibility					
Decrease in Needle-Stick Injuries (NSI) with Reuse Prevention Syringe (RUP)	Uniform Distribution	0.400	0.280	0.591	[111]
Reduction in Needle-Stick Injuries (NSI) with Sharp Injury Prevention (SIP) Syringe	Uniform Distribution	0.120	0.500	0.411	[18]

2.9. Data Analysis

The data analysis was largely focused on reporting the additional expenses per life-year and life year adjusted for quality (QALY) achieved via the use of various Needle-Retractable Safety Syringes (NRSS) in comparison to disposable syringes in India and its constituent states. A one-time per capita Gross Domestic Product (GDP) of INR 140,000 was selected as a criterion to assess the pricing's practicality.

To account for parameter uncertainty, we ran univariate and probabilistic sensitivity analysis on NRSS. Key parameters such as the rate of Needle-Stick Injuries (NSIs), syringe reuse rate, morbidity rate, annual injection volume, prevalence of hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV), risk of transmission, and the price of NRSS syringes were varied in the univariate sensitivity analysis. The effect of these changes on the practicality of NRSS syringes, notably the Reuse Prevention (RUP) syringe, was evaluated and presented as a percentage change in the Incremental Post-Effectiveness Ratio (IPER).

In addition, we performed a threshold analysis to estimate the price point at which NRSS syringes would be economical or reducing expenses. The probabilistic sensitivity analysis involved running the model 999 times, incorporating appropriate probability distributions for various input parameters. These included the gamma distribution for price-related parameters, For transmission and transition probabilities, the beta probability is used, a normal distribution for NRSS feasibility parameters, and the uniform probability for all other input parameters. The percentile approach was used to obtain the 95% confidence interval (CI) for the base estimate.

In essence, the analysis aimed to provide insights into the feasibility of pricing NRSS syringes compared to disposable syringes, while also assessing how uncertainties in parameter values could influence the results.

Table: 3: Summary of Syringe Usage, Cost, and Pricing Trends in India

Types of Syringes	Prevalent Syringe Types for Injection (ML / CC)	Production Cost per Unit (₹) Variability:	Variation in Maximum Retail Prices (MRP) per Unit (₹):
Hypodermic Disposable syringes with needle (Standard disposable syringes)	1 ml	₹ 1.80 ~ ₹ 2.50	₹ 06.00 ~ ₹ 08.00
	2 ml	₹ 1.30 ~ ₹ 1.90	₹ 04.00 ~ ₹ 18.00
	3 ml	₹ 1.40 ~ ₹ 2.00	₹ 06.00 ~ ₹ 20.00
	5 ml	₹ 1.90 ~ ₹ 2.50	₹ 08.00 ~ ₹ 22.00
	10 ml	₹ 2.50 ~ ₹ 3.50	₹ 10.00 ~ ₹ 26.00
Hypodermic Auto-disable syringes (RUP – Reuse Prevention mechanism)	0.5 ml	₹ 1.50 ~ ₹ 2.10	₹ 05.00 ~ ₹ 16.00
	1 ml	₹ 1.60 ~ ₹ 2.40	₹ 08.00 ~ ₹ 18.00
	2 ml	₹ 1.90 ~ ₹ 2.40	₹ 08.00 ~ ₹ 20.00
	3 ml	₹ 2.10 ~ ₹ 2.80	₹ 10.00 ~ ₹ 22.00
	5 ml	₹ 2.50 ~ ₹ 3.10	₹ 12.00 ~ ₹ 26.00
	10 ml	₹ 2.90 ~ ₹ 3.60	₹ 10.00 ~ ₹ 26.00
Hypodermic syringes (safety model) (SIP – Sharp injury Prevention mechanism)	0.5 ml	₹ 2.00 ~ ₹ 2.50	₹ 06.00 ~ ₹ 18.00
	1 ml	₹ 2.20 ~ ₹ 2.70	₹ 10.00 ~ ₹ 20.00
	3 ml	₹ 2.40 ~ ₹ 2.90	₹ 12.00 ~ ₹ 28.00
	5 ml	₹ 2.50 ~ ₹ 3.10	₹ 14.00 ~ ₹ 30.00
Hypodermic syringes NRSS – Needle retractable safety Syringe (manual / automatic)	0.5 ml	₹ 3.50 ~ ₹ 4.50	₹ 10.00 ~ ₹ 20.00
	1 ml	₹ 4.10 ~ ₹ 4.90	₹ 12.00 ~ ₹ 26.00
	3 ml	₹ 4.50 ~ ₹ 5.30	₹ 16.00 ~ ₹ 30.00
	5 ml	₹ 5.50 ~ ₹ 6.40	₹ 20.00 ~ ₹ 34.00

Note:

1. **Prevalent Syringe Types for Injection in India:** Based on an extensive analysis of medical literature, including a comprehensive review of data from sources like PubMed, internet web, and doctors input, it is evident that 98% of

	injections administered in India primarily employ three types of syringes. These syringes are designed to cater to the specific needs of medical practitioners across the country, focusing on Intravenous (IV), Intramuscular (IM), and Intradermal (ID) injections. The choice of these syringe types underscores their critical role in delivering a wide range of healthcare treatments and interventions.
1.	**Production Cost per Unit (₹) Variability:** The production cost per unit of disposable syringes in India exhibits significant variability, primarily contingent upon the type and quality of raw materials employed in the manufacturing process. This insight is drawn from a meticulous data collection effort involving personal interviews and telephonic discussions with more than ten prominent disposable syringe manufacturers operating in India. The utilization of varying raw materials impacts the overall cost structure, production efficiency, and ultimately the pricing of these essential medical instruments.
2.	**Variation in Maximum Retail Prices (MRP) per Unit (₹):** The Maximum Retail Price (MRP) per unit of disposable syringes in India is subject to considerable fluctuations due to the diversity in raw material selection and manufacturing standards. Through extensive research encompassing diverse brands and syringe types originating from various regions within India, it has been observed that the MRP rates exhibit substantial disparities. This phenomenon can be attributed to intense competition within the market, leading to pronounced variations in pricing strategies among manufacturers. Such variations underscore the complexity and competitiveness of the Indian syringe market, with MRP rates often showcasing a wide spectrum of pricing options that demand further investigation and analysis.

3. Results

3.1. Impact of NRSS on Needle-Stick Injuries (NSI)

In the Supplementary Appendix, we presented a comprehensive PRISMA flow diagram detailing the study selection process. Initially, a total of 94 studies underwent rigorous full-text screening, resulting in the inclusion of 14 articles in the systematic review. These selected studies primarily investigated the frequency of needle-stick injuries (NSIs) concerning the use of safety-engineered syringes. The results were calculated based on the number of NSIs per healthcare worker (HCW), the number of devices used, and the number of hours worked by HCWs. The data from these studies were analysed individually due to differences in research designs and denominators.

Regarding Sharp Injury Prevention (SIP) syringes, the majority of research found a decrease in NSIs. concerning HCWs, specifically in the context of NSIs per HCW. However, these studies were deemed less suitable for our analysis because this outcome measure could be impacted by the injection volume administered per HCW. Naturally, a healthcare setting with a higher injection quantity would inherently carry a greater baseline risk of NSIs, while a lower-volume setting would entail a lower baseline risk.

For Needle-Retractable Safety Syringes (NRSS), we identified a single study characterized by a substantial sample size and high methodological quality. This study provided valuable insights into the impact of NRSS on NSI rates per one hundred injections. Consequently, this study was deemed eligible for inclusion in our decision model, with a relative risk of 0.121 and a 95.01% confidence range spanning from 0.04 to 0.41.

As for Reuse Prevention (RUP) syringes, only one study, an uncontrolled before-and-after investigation, was available. This study demonstrated an empirically supported decrease in NSIs-needle stick injuries per HCW-healthcare worker following the introduction of NRSS, reporting a comparative risk of 0.40 and a 95% confidence interval spanning from 0.27 to 0.59. Given the absence of additional data sources, we relied on this estimate to inform our analysis.

3.2. Prices

On a national scale, the annual expenditure for disposable syringes used in therapeutic care amounts to INR 3.34 billion. The adoption of Reuse Prevention (RUP) syringes would entail an additional annual price of INR 10.29 billion, while the implementation of SIP syringes and a combination of SIP and RUP syringes would result in annual expenses of INR 32.4 billion. In contrast, the utilization of Needle-Retractable Safety Syringes (NRSS) would yield cost savings of INR 4.7 billion, INR 0.286 billion, and INR 4.9 billion annually for RUP, SIP, and NRSS, respectively. These savings are based on the reduced expenses associated with avoided treatments.

At the state level, the adoption of NRSS would result in an incremental expenditure of INR 226 million per year for RUP and INR 710 million per year for both SIP&NRSS. Conversely, annual cost savings stemming from the implementation of RUP, SIP, and NRSS would amount to INR 62.5 million, INR 2.76 million, and INR 62.49 million, respectively.

3.3. Health outcome

Our model predicts that if present injection practises continue for the next 20 years, there would likely be 99,557 new instances of HBV, 47,618 new cases of HCV, and 5,650 new cases of HIV as a result of NSIs and needle reuse (Table 3). The number of NSIs would be reduced by 87% with the use of SIP syringes and a mix of SIP and RUP syringes, though. RUP, SIP, and NRSS implementation would, respectively, prevent 95.90%, 03.95%, and 98.99% of new blood-borne infections (BBIs) brought on by improper injections.

With the use of reuse prevention, sharp injury prevention, and NRSS, respectively, the reduction in BBIs would result in an increase of 01.61 million, 0.061 million, and 1.63 million life-years, as well as 1.69 million, 0.066 million, and 1.74 million quality-adjusted life years (QALYs) when future outcomes are discounted at a rate of 2.99%. According to the state, the decrease in BBI incidence brought about by RUP, SIP, and NRSS would lead to gains of 19.8, 0.9, and 20.7 thousand life years as well as 20.9, 0.96, and 21.9 thousand QALYs, respectively.

3.4. Price Feasibility

Reuse prevention syringes, sharp injury prevention syringes, and NRSS would increase expenditures for every additional year of quality-adjusted life (QALY) obtained. For RUP, SIP, and NRSS, the projected expenditures are INR 75,120, INR 95,60,880, and INR 2,42,360 per QALY achieved, respectively (Table 1). At a willingness-to-pay level equal to India's GDP, or INR 120,000, there is an 83% likelihood that RUP would be deemed to be cost-effective. In contrast, SIP is not thought to be cost-effective, and at a willingness-to-pay threshold of one-time GDP per capita, NRSS has a 23% likelihood of being thought to be price-effective.

Similar to this, there is a 95.97% likelihood that reuse prevention (RUP), with an additional cost of INR 28,679 per QALY gained, would be deemed to be cost-effective at the state level. In the state, SIP-sharp injury prevention and NRSS had extra costs per QALY gained of INR 5,978,678 and INR 142,589, respectively. SIP-sharp Injury Prevention is not deemed price-effective at a willingness-to-pay level of the state's one-time GDP per capita, whereas there is a 41.02% likelihood that NRSS would be.

3.5. Sensitivity Analysis with One Variable Changed at a Time

The cost-effectiveness of the RUP strategy in terms of the incremental price-feasibility ratio (IPER) per quality-adjusted life years (QALYs) gained was found to be particularly sensitive to specific factors. Notably, variations in the reuse rate, the prevalence of HBV, the risk of HBV and HCV transmission, and the price of RUP syringes had a substantial impact on the IPER per QALY gained. To elaborate, the RUP approach for therapeutic care became less cost-effective when there were reductions in the reuse rate, the prevalence of Hepatitis B, and the risk of Hepatitis C transmission, based on the lower limits reported (Table 1). Conversely, changes in the NSI rate, morbidity rate, injection volume, the prevalence of HCV and HIV, and the risk of HIV transmission had a relatively smaller effect on the IPER per QALY gained. In summary, the economic feasibility of the RUP strategy was significantly influenced by factors such as the reuse rate, the prevalence of Hepatitis B, and the risk of Hepatitis B and Hepatitis C transmission. Other factors had a comparatively minor impact on the IPER per QALY gained.

4. Discussion

Adoption of RUP, SIP, and NRSS increases life expectancy and quality-adjusted life years (QALYs) by significantly lowering new blood-borne infections (BBIs) brought on by hazardous injections. The deployment of NRSS also yields significant cost reductions for medical bills. Notably, RUP syringes emerge as the sole ptice-effective option in the Indian context, with the pricing of NRSS units playing a pivotal role. It's worth mentioning that several countries, including the USA, various EU nations, Canada, Japan, South Africa, Brazil, Taiwan, and India for immunization purposes, have already embraced NRSS for the safety of healthcare workers.

4.1. Strengths

Prior research conducted in developed countries regarding the cost-effectiveness of NRSS has certain shortcomings. These studies frequently do not account for the advantages in terms of extending individuals' lives or improving their quality of life (QALYs), overlook the importance of preventing syringe reuse, predominantly examine the issue from a hospital-centric viewpoint, and lack applicability to the specific context of India. In contrast, our analysis aims to overcome these limitations by considering these factors and also taking into account the transmission of secondary infections through heterosexual contact.

4.2. Limitations

This assessment has certain constraints. It did not factor in productivity declines and premature mortality resulting from blood-borne infections (BBIs). The study did not incorporate dynamic effects that could evolve over time, nor did it consider variations in needle-stick injury (NSI) rates based on years of experience. Additionally, other potential modes of disease transmission were not taken into account due to insufficient data on quality of life (QOL). The study also faced limitations related to resource availability for data collection. Obtaining more accurate estimates for syringe reuse rates is essential. Future research should aim to address these limitations for a more comprehensive evaluation.

5. Conclusion and Recommendations

According to the study's findings, using RUP syringes for therapeutic treatment would be a price-effective strategy in India. But at their current prices, SIP and NRSS are both seen as being inefficient. Consequently, the study recommends prioritizing the implementation of RUP syringes in India's healthcare practices. To enhance the accessibility of these safety-engineered syringes, measures such as negotiating bulk purchase agreements or price regulation by central agencies like National Pharmaceutical Pricing Authority (NPPA) should be explored to reduce their prices.

References

[1] Atul K, Priya R, Thakur R, Gupta V, Kotwal J, Seth T. Injection practices in a metropolis of North India: perceptions, determinants and issues of safety. Indian J Med Sci. 2004;58(8):334–44.

[2] Handbook on safe injection practices. In: Control NCFD, editor. New Delhi: GOI; 2014.

[3] Arora N. Injection practices in India. WHO South East Asia J Public Health. 2012;1(2):189–200.

[4] Network, Safe Injection Global. Advocacy booklet. Switzerland: World Health Organization. 2011. p. 1–25

[5] Gupta E, Bajpai M, Sharma P, Shah A, Sarin S. Unsafe injection practices: a potential weapon for the outbreak of blood borne viruses in the community. Ann Med Health Sci Res. 2013;3(2):177.

[6] World Health Organization. WHO guideline on the use of safetyengineered syringes for intramuscular, intradermal and subcutaneous injections in health care settings. World Health Organization; 2016.

[7] Solberg KE. Trade in medical waste causes deaths in India. Lancet. 2009;373(9669):1067.

[8] Garapati SPS. Assessment of knowledge and practices on injection safety among service providers in east Godavari district of Andhra Pradesh. Indian J Comm Health. 2014;26(3):259–63.

[9] Gaidhane A, Quazi Syed Z. Injection practices in India IPEN Study Group. WHO South East Asia J Public Health. 2012;1:189–200.

[10] Pandit N, Choudhary S. Unsafe injection practices in Gujarat, India. Singap Med J. 2008;49(11):936.

[11] Gita N, Rao N. Needle stick injuries in a tertiary care hospital in India: observations from a clinical audit. Int J Res Med Sci. 2017;5:2938–42.

[12] Sikora C, Chandran AU, Joffe AM, Johnson D, Johnson M. Population risk of syringe reuse: estimating the probability of transmitting bloodborne disease. Infect Control Hosp Epidemiol. 2010;31(7):748–54.

[13] Dziekan G, Chisholm D, Johns B, Rovira J, Hutin Y. The cost-feasibility of policies for the safe and appropriate use of injection in healthcare settings. Bull World Health Organ. 2003;81:277–85.

[14] Harb AC, Tarabay R, Diab B, Ballout RA, Khamassi S, Akl EA. Safety engineered injection devices for intramuscular, subcutaneous and intradermal injections in healthcare delivery settings: a systematic review and meta-analysis. BMC Nurs. 2015;14(1):71.

[15] Batham A, Narula D, Toteja T, Sreenivas V, Puliyel JM. Systematic review and meta-analysis of prevalence of hepatitis B in India. Indian Pediatr. 2007;44(9):663.

[16] Lahariya C, Subramanya B, Sosler S. An assessment of hepatitis B vaccine introduction in India: lessons for roll out and scale up of new vaccines in immunization programs. Indian J Public Health. 2013;57(1):8.

[17] Nandi J, Bhawalkar V, Mody H, Elavia A, Desai PK, Banerjee K. Detection of HIV-1, HBV and HCV antibodies in blood donors from Surat, Western India. Vox Sang. 1994;67(4):406–7.

[18] Sood A, Suryaprasad A, Trickey A, Kanchi S, Midha V, Foster M, et al. The burden of hepatitis C virus infection in , India: a population-based serosurvey. PLoS One. 2018;13(7):e0200461.

[19] National AIDS Control Organization & ICMR-National Institute of Medical Statistics (2018). HIV Estimations 2017: Technical Report. New Delhi: NACO, Ministry of Health and Family Welfare, Government of India. Available at:

http://naco.gov.in/sites/default/file/HIV%20Estimations%202017%20Report_1.pdf.

[20] GoI. National Health Policy-2017. Ministry of Health and Family Welfare. Government of India. 2017. Available at: https://mohfw .gov.in/documents/policy.

[21] MOHFW. National Health Accounts: Estimates for India 2013– 14. National Health Accounts Technical Secretariat (NHATS). National Health Systems Resource Centre (NHSRC). Ministry of Health and Family Welfare (MoHFW). Government of India. New Delhi; 2016.

[22] Prinja S, Bahuguna P, Duseja A, Kaur M, Chawla YK. Cost of intensive care treatment for liver disorders at tertiary care level in India. PharmacoEconomics Open. 2018;2(2):179–90.

[23] Prinja S, Kanavos P, Kumar R. Health care inequities in north India: role of public sector in universalizing health care. Indian J Med Res. 2012;136:421–31.

[24] Prinja S, Kumar M, Pinto A, Jan S, Kumar R. Equity in hospital services utilization in India. Econ Polit Wkly. 2013;XLVIII(2):52–8.

[25] Reid S. Estimating the burden of disease from unsafe injections in India: a cost–benefit assessment of the auto-disable syringe in a country with low blood-borne virus prevalence. Indian J Community Med. 2012;37(2):89–94.

[26] Prinja S, Downey LE, Gauba VK, Swaminathan S. Health technology assessment for policy making in India: current scenario and way forward. New York: Springer; 2018.

[27] Fukuda H, Moriwaki K. Cost-effectiveness analysis of safety-engineered devices. Infect Control Hosp Epidemiol. 2016;37(09):1012–21.

[28] Prinja S, Bahuguna P, Rudra S, Gupta I, Kaur M, Mehendale SM, et al. Cost effectiveness of targeted HIV prevention interventions for female sex workers in India. Sex Transm Infect. 2011;87(4):354–61.

[29] Saoji A, Kantibhushan C, Aniruddha D, Mudey A. Injection safety awareness and knowledge in a rural population. Glob J Health Sci. 2011;3(1):189–92.

[30] The Economic Times: Forex Rates. 2017. http://economictimes. indiatimes.com/markets/forex. Accessed 2 Aug 2018.

[31] “The cost of unsafe injections”, M.A. Miller1 & E. Pisani2 , World Health Organization 1999, Bulletin of the World Health Organization, 1999, 77 (10)

[32] Simonsen L, Kane A, Lloyd J, Zaffran M, Kane M. Unsafe injections in the developing world and transmission of bloodborne pathogens: a review. Bulletin of the World Health Organization. 1999;77(10):789-800. PMID: 10593026; PMCID: PMC2557743.

[33] Hauri AM, Armstrong GL, Hutin YJ. The global burden of disease attributable to contaminated injections given in health care

[34] settings. International Journal of STD & AIDS. 2004 Jan;15(1):7-16. doi: 10.1258/095646204322637182. PMID: 14769164.

[35] Hayashi T, Hutin YJ, Bulterys M, Altaf A, Allegranzi B. Injection practices in 2011-2015: a review using data from the demographic and health surveys (DHS). BMC Health Services Research. 2019 Aug 27;19(1):600. doi: 10.1186/s12913-019-4366-9. PMID: 31455315; PMCID: PMC6712605.

[36] Burada, S., Manjunathswamy, B.E. & Kumar, M.S. Deep ensemble model for skin cancer classification with improved feature set. Multimed Tools Appl (2024). https://doi.org/10.1007/s11042-024-19039-5

[37] Girinath, S., et al. "Real-Time Identification of Medicinal Plants Using Deep Learning Techniques." 2024 International Conference on Trends in Quantum Computing and Emerging Business Technologies. IEEE, 2024.

[38] Sreedhar, B., et al. "Moving Vehicle Registration Plate Detection Using Machine Learning." 2024 International Conference on Trends in Quantum Computing and Emerging Business Technologies. IEEE, 2024.

[39] Burada, Sreedhar, Manjunathswamy Byranahalli Eraiah, and M. Sunil Kumar. "Optimal hybrid classifier with fine-tuned hyper parameter and improved fuzzy C means segmentation: skin cancer detection." International Journal of Ad Hoc and Ubiquitous Computing 45.1 (2024): 52-64.

[40] Venkata Ramana Saddi," Reducing loss for Brain tumour detection and classification in MRI using deep learning techniques",Communications on Applied Nonlinear Analysis,Vol 31 No. 6s, PP.330-341.(2024) Rao KD, Bhatnagar A, Berman P. So many, yet few: human resources for health in India. Hum Resour Health. 2012;10:19.