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Common Accidents in Paediatric Practice; Current Evidence for a 4-Pronged Strategic Framework for Prevention

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ABSTRACT

Accidents are untoward events that occur inadvertently and lead to injuries or diseases. In healthcare settings, both patients and healthcare workers are at risk of being victims. By virtue of children's evolving developmental maturity, caring for them puts all parties more at risk. Having a comprehensive framework to prevent accidents in paediatric practice is therefore crucial.

This paper aims to utilize the principles of primordial, primary, secondary and tertiary preventive strategies to design a framework for preventing accidents in paediatric healthcare settings, in the light of current evidence. Common cases selected to exemplify the framework include needle stick injury, exposure to blood-borne infections, post-injection traumatic neuropathy, post-injection abscess, Nicolau syndrome, fluid overload, and drug overdose.

Vital to preventing the selected injuries and disorders is a multidisciplinary team of relevant experts, including paediatricians, paediatric surgeons, orthopaedic surgeons, burns and plastic surgeons, neurosurgeons, toxicologists, pharmacists, microbiologists, infectious disease physicians, anaesthetists, and public health physicians.

KEYWORDS: Accidents, Paediatric practice, 4-pronged preventive strategy, Multidisciplinary team

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INTRODUCTION

Accidents have been defined as unexpected and unintentional events that lead to injury.[1] In healthcare settings, accidents do not only result in physical injuries; they could potentially have biological and psychological impacts on patients, caregivers, healthcare providers and support staff. Children, by virtue of their evolving physical and cognitive maturity, pose more risk of accidents in hospitals and clinics. It is therefore crucial for paediatric healthcare workers and managers to always anticipate and avoid such incidents.

This paper elucidates a critical strategic framework for preventing accidents in paediatric practice. Common cases were selected to exemplify the framework; they include needle stick injury (NSI), exposure to blood-borne infections, post-injection traumatic neuropathy, post-injection abscess, Nicolau syndrome, fluid overload, and drug overdose. The strategies are presented within the context of a 4-pronged interventional model, namely the primordial and Leavell's primary, secondary and tertiary levels of prevention.[2,3]

THE FOUR LEVELS OF PREVENTION

Primordial strategy is a health promotive population-based measure that prevents the emergence of risk factors for injuries and diseases.[4,5] Primary strategy is a specific measure that targets susceptible populations; it reduces the incidence of a specified injury or disease by addressing the risk factors for or increasing resistance to the morbidity.[2,5,6] Secondary strategy targets the latent ("hidden") stage of a disease or injury; it limits progression to the symptomatic stage through early detection and prompt intervention, thus reducing the

prevalence.[2,4] Tertiary strategy targets the symptomatic stage; it limits disability at the early phase of the injury or disease, and rehabilitates the victim at the late phase.[2,4,6]

Prevention of needle stick injury and exposure to blood-borne infections

Primordial strategy: **(a)** Training of clinical and support staff on NSI and standard precautions; **(b)** Training of clinical staff on phlebotomy techniques in children; **(c)** Designating trained phlebotomists to obtain blood samples and secure intravenous (IV) access in children.

Primary strategy: **(a)** Observing standard precautions when performing procedures in children; **(b)** Placing sharps containers at multiple locations in the wards and clinics; **(c)** Pre-exposure prophylaxis (PrEP) with hepatitis B vaccine (HBVac) given to all healthcare workers and support staff.

Secondary strategy: **(a)** Washing wound/breeched skin thoroughly (without squeezing) with water and soap.[7] Alcohol, a virucidal agent to human immunodeficiency virus (HIV), hepatitis B virus (HBV) and hepatitis C virus (HCV), can also be applied. Other virucidal agents include chlorhexidine, iodophors and chloroxylenol; **(b)** Irrigating mucous membrane with large amount of water (eyes with saline or water); **(c)** Incident reporting;

HIV post-exposure intervention [8,9]

(d) Unless known to have HIV, the source is tested for HIV with a fourth-generation combined antigen-antibody test; **(e)** The victim is tested for HIV infection; **(f)** If the benefit of antiretroviral (ARV) therapy outweighs the risk of infection and potential drug toxicities, post-exposure prophylaxis (PEP) is offered to the victim within 1-2 hours while awaiting results *(ARV PEP Regimen: Children <10 years old – Zidovudine + Lamivudine + Lopinavir-ritonavir, Adolescents and adults – Tenofovir + Lamivudine/Emtricitabine + Lopinavir-ritonavir/Atazanavir-ritonavir)*; **(g)** PEP is discontinued after four weeks or when the source is confirmed to be HIV negative and there is no suspicion of acute HIV infection;

HBV post-exposure intervention [10]

(h) The source is tested for hepatitis B surface antigen (HBsAg) unless the source is known to have HBV infection, or the victim had completed the standard HBVac series *(given at 0, 1 and 6 months)* and is a vaccine responder *[antibody to HBsAg (anti-HBs) titre is ≥10 mIU/mL after complete series]* prior to exposure; **(i)** The victim is tested for HBsAg and anti-HBs *(anti-HBs is tested only if fully vaccinated)*; **(j)** PEP, comprising hepatitis B immunoglobulin (HBIG) and HBVac, is offered to the victim if the source is positive for HBsAg and the victim is a vaccine non-responder or is unvaccinated/incompletely vaccinated. If eligible for PEP, HBIG is given within 24 hours or not later than seven days, HBVac is administered simultaneously at a different site, a second dose of HBIG is given one month after, and HBVac series are completed; **(k)** Follow-up testing for HBsAg and antibody to hepatitis B core antigen (anti-HBc) is done six months after exposure. A health worker can provide care to patients within this period, but cannot donate body fluids, tissues or organs;

HCV post-exposure intervention [11]

(l) The source is tested for HCV ribonucleic acid (RNA), or antibody to HCV (anti-HCV) if HCV RNA is not available; **(m)** The victim is tested for anti-HCV within 48 hours provided the source is positive for HCV RNA/anti-HCV; **(n)** If the victim's anti-HCV is positive, HCV RNA is assayed – if negative, it is repeated at least three weeks following exposure. Positive HCV RNA within 48 hours indicates pre-existing HCV infection and requires immediate referral for comprehensive care. The origin of infection is indeterminable after at least three weeks if HCV RNA becomes positive; **(o)** If the victim's initial anti-HCV is negative, HCV RNA is assayed at least three weeks following exposure, or anti-HCV is repeated at least six weeks after. Positive HCV RNA at three or six weeks indicates source-induced HCV infection, while a negative result does not require further testing; **(p)** Early diagnosis of source-induced HCV infection and prompt initiation of treatment are crucial, as current evidence does not support PEP for HCV infection.

Tertiary prevention: *NSI is often associated with pain and emotional stress caused by exposure to potentially serious infections, hence*, **(a)** Pain should be controlled with analgesics; **(b)** Post-exposure testing should be expedited; **(c)** PEP counselling should be as explicit as possible; **(d)** Victim should be referred early for preemptive psychotherapy; **(e)** Victims with symptomatic source-induced HIV, HBV or HCV infection should be referred early for comprehensive care.

Prevention of post-injection traumatic neuropathy, post-injection abscess and Nicolau syndrome

Primordial strategy: **(a)** Formulating restrictive policies on indications for injections in children; **(b)** Creating public awareness to correct the misconception about the "magic" effect of injections; **(c)** Enforcing national and local laws prohibiting quackery **(d)** Employing qualified clinical staff into children's hospitals, clinics and wards.

Primary strategy: **(a)** Using the right injection sites *[Intramuscular (IM) injections: children up to two years – vastus lateralis of anterolateral thigh, children 3 to 10 years – deltoid muscle/vastus lateralis of anterolateral thigh, 11 to 18 years old – deltoid muscle, Subcutaneous (SC) injections: ≤ 1 year old – thigh area, ≥ 1 year old – upper outer triceps area, Intradermal (ID) injections: < 2 months old – deltoid area, ≥2 months old – proximal ventral forearm/proximal dorsal forearm/deltoid area]* [12–14] **(b)** Using the right needle gauge *(IM: 22-25, SC: 23-25, ID: 25-26)*, right needle length *(IM: 16-32 mm, SC: 16 mm, ID: 12.7 mm)*, right angulation *(IM: 90^0, SC: 45^0)*, right technique *(IM: Z-track)*, right injection depth *(ID: 0.7 mm)* and right patient positioning [12–16]; **(c)** Avoiding the gluteal region in children < five years old [16,17]; **(d)** If the gluteus must be used in children ≥ five years old, the ventrogluteal *(gluteal triangle)* rather than dorsogluteal region *(upper outer quadrant)* is preferred

[16,18,19]; **(e)** Using a special device to deliver ID injections to enhance precision [14]; **(f)** Adopting percutaneous route for BCG vaccination [20]; **(g)** Minimizing glass particle contamination of injections by partially wrapping the ampoule neck, breaking the ampoule from an outward direction, and using filter needle for injection [21]; **(h)** Minimizing the risk of post-injection abscess (PIA) by maintaining a sterile field of injection and adequately diluting drug solutions. Hypertonic drug solutions have been shown to be an important risk factor for PIA [22]; **(i)** Minimizing the risk of Nicolau syndrome by allowing crystals in refrigerated drug to dissolve before injecting, and avoiding periarterial injection [23,24]; **(j)** Properly restraining an uncooperative child during injection administration; **(k)** Training and retraining of staff on standard sequential technique and recommended anatomical sites for injections in children.[25,26]

Secondary strategy:

Traumatic injection neuropathy (TIN)

(a) Recognizing the early symptoms and signs *(pain, paraesthesia, causalgia)*; **(b)** Incident reporting; **(c)** Evaluating with magnetic resonance neurography, electromyography, nerve conduction studies; **(d)** Immediate flooding of subgluteal space with physiologic fluid following emergence of early symptoms and signs [16]; **(e)** Controlling pain with acetaminophen, gabapentin or tricyclic antidepressant following emergence of early symptoms and signs [27]

Nicolau syndrome (embolia medicamentosa or livedoid dermatitis)

Presents with intense pain immediately after injection, followed by erythema and violaceous patch within minutes to hours. Later turns haemorrhagic, forms deep ulcer and heals with atrophic scar in weeks to months.[23] **(f)** Recognizing the early symptoms and signs; **(g)** Incident reporting; **(h)** Evaluating the extent of injury with ultrasonography, magnetic resonance imaging; **(i)** Use of cold compress is discouraged *(it may be of no benefit and may worsen complication)* [28,29]; **(j)** Controlling pain with analgesics.

Tertiary strategy:

Traumatic injection neuropathy

(a) Early recognition of paralytic TIN; **(b)** Early referral of paralytic TIN for physiotherapy [30]; **(c)** Surgery – surgical exploration within 3 to 6 months of injury, surgical nerve repair, dynamic elastic splint, musculotendinous transposition/femoral lengthening[16]; **(d)** Trans-sacral methylprednisolone block for sciatic TIN [31]; **(e)** Follow-up check for nerve regeneration

Post-injection abscess

(f) Controlling pain with acetaminophen or ibuprofen; **(g)** Drainage of BCG-induced suppurative lymphadenitis *[BCG injection site (deltoid) reaction and abscess do not require treatment in immunocompetent individuals]* [32]; **(h)** Treatment of extra-deltoid BCG-induced tubercular cold abscess using anti-tubercular drugs, clarithromycin and antigravity drainage [33–35]; **(i)** Prompt drainage of infectious PIA and commencement of appropriate antimicrobial therapy;

Nicolau syndrome [23,24,36,37]

(j) Controlling pain with acetaminophen or ibuprofen; **(k)** Bed rest; **(l)** Debridement; **(m)** Dressing; **(n)** Vasoactive agent – alprostadil, pentoxifylline; **(o)** Anticoagulant – subcutaneous heparin; **(p)** Hyperbaric oxygen; **(q)** Topical steroid; **(r)** Surgery *(rarely indicated)*

Prevention of fluid overload

Primordial strategy: **(a)** Formulating restrictive policies on the indications for intravenous fluid (IVF) in children; **(b)** Creating public awareness to correct the misconception about the "magic" effect of IVF; **(c)** Enforcing national and local laws prohibiting quackery; **(d)** Employing qualified staff into children's wards, clinics, dialysis units and dispensaries; **(e)** Procuring quality-assured paediatric fluid delivery sets and machines.

Primary strategy: **(a)** Formulating evidence-based protocol for fluid therapy and renal replacement therapy on a 'case by case' basis; **(b)** Adapting fluid regimen based on availability of facility for haemodynamic monitoring [38]; **(c)** Selecting the type of maintenance fluid on the basis of serum sodium level and the risk of developing syndrome of inappropriate antidiuretic hormone [39]; **(d)** Appropriate calculation of maintenance fluid requirement *(using Holliday-Segar formula)* **(e)** Using the minimum volume of fluid for drug administration [40]; **(f)** Using infusion pump to deliver IVF, parenteral nutrition, blood products and drug infusions; **(g)** Close haemodynamic monitoring during administration of IVF and blood; **(h)** Regular monitoring of delivery system during fluid administration [41]; **(i)** Regular fluid balance check during fluid administration; **(j)** Training and retraining of staff on calculation of fluid rate.

Secondary strategy: **(a)** Regular calculation of %fluid overload $\left(\frac{Daily\ fluid\ intake\ (L) - Total\ fluid\ output\ (L)}{Baseline\ body\ weight\ (kg)} \times 100\right)$ during fluid administration. The patient remains asymptomatic until %fluid overload approaches 10%.[42–44]; **(b)** In critically ill and kidney-impaired patients, screening with lung ultrasound *(lung ultrasound is more sensitive at the asymptomatic phase than auscultation and chest radiograph)*, echocardiography, bioimpedance spectroscopy, natriuretic peptides, inferior vena cava collapsibility index, relative blood volume monitoring [42,43,45]; **(c)** Stopping fluid therapy or reducing fluid rate **(d)** In critically ill patients, administering low dose diuretic, e.g., 0.2 mg/kg of IV furosemide. [40]

Tertiary strategy: **(a)** Recognizing clinical features of fluid overload *(new-onset oedema, new tachypnoea/dyspnoea, new tachycardia, jugular venous distension, pulmonary rales, hypoxia, increasing liver size, rapid weight gain)* [40,42]; **(b)** Administering therapeutic doses of diuretics, e.g., furosemide, torsemide, bumetanide, thiazide diuretic, spironolactone, aminophylline, theophylline *(single prophylactic dose of theophylline is recommended in severe*

perinatal asphyxia – a risk factor for acute kidney injury and fluid overload) [40,42]; **(c)** Extracorporeal therapies, e.g., renal replacement therapy [42]; **(d)** Avoidance of sodium-containing drugs in kidney-impaired patients [43]; **(e)** Early switch to enteral fluid and nutrition; **(f)** Early ambulation.

Prevention of drug overdose

Primordial strategy: **(a)** Enforcing national and local laws prohibiting quackery; **(b)** Employing qualified staff into children's wards, clinics and dispensaries.

Primary strategy: **(a)** Formulating evidence-based protocol for drug therapy; **(b)** Providing drug formulary in wards, clinics and dispensaries, and its regular use by healthcare workers; **(c)** Training and retraining of clinical staff on calculation of oral and parenteral drug volume; **(d)** Keeping all oral and parenteral drugs away from the patient's bedside; **(e)** Only clinical staff should administer oral and parenteral drugs.

Secondary strategy: **(a)** Stopping administration of the offending drug; **(b)** Laboratory investigations, as appropriate, e.g., toxicologic screen of blood and urine, arterial blood gases, liver function test, renal function test; **(c)** Activated charcoal, if: the offending drug is adsorbable, the risk of toxicity is significant, the time since drug ingestion is < 1 hour, there is no contraindication to use, the benefits outweigh the risks [46]; **(d)** Stomach pumping or gastric lavage *(current evidence show safety concerns and minimal benefits)* [46]; **(e)** Induced emesis *(No longer recommended)* [46]; **(f)** Whole bowel irrigation – done with osmotically-balanced polyethylene glycol to reduce the gastro-intestinal transit time. Useful in overdose of sustained-release drugs (e.g., iron preparations) [46]; **(g)** Urinary alkalinization using isotonic IVF bolus *(cautiously administered)* and IV sodium bicarbonate, provided the offending drug is: a weak acid with pKa 3.0 to 7.5, minimally bound to protein, primarily distributed in the extracellular space, eliminated by the kidneys largely unchanged [47]; **(h)** Forced diuresis *(not recommended)* [48]; **(i)** IV lipid emulsion – promotes sequestration of drug in the lipid phase. Useful in overdose of local anaesthetic agents, calcium channel and beta blockers [46]; **(j)** Antidote, if existent and indicated; **(k)** Establishment of a poison control unit. [49]

Tertiary strategy: **(a)** Early recognition of classic toxidrome *(sympathomimetic, anticholinergic, cholinergic, sedative, hypnotic, hallucinogenic symptoms and signs)* [46]; **(b)** Early recognition of signs and symptoms of specific drug toxicity; **(c)** Antidote, if existent; **(d)** IV lipid emulsion – useful in cardiovascular collapse following overdose of local anaesthetic agent [46]; **(e)** Urinary alkalinization, if applicable; **(f)** Haemodialysis, if applicable; **(g)** Haemoperfusion, if applicable; **(h)** Albumin dialysis, if applicable [50]; **(i)** Haemofiltration, if applicable and where haemodialysis is not available; **(j)** Exchange blood transfusion, if applicable and where haemodialysis is not available; **(k)** Therapeutic plasma exchange, if applicable [50,51]; **(l)** Cerebrospinal fluid exchange – useful in overdose of intrathecal methotrexate [50]; **(m)** Extracorporeal membrane oxygenation and emergency cardiopulmonary bypass, if indicated. [50]

CONCLUSION

Accidents in paediatric healthcare settings should always be anticipated, and efforts should made at preventing them. The 4-pronged strategic framework presented above can be a useful tool to minimize risks to patients, caregivers, healthcare workers, and support staff.

A multidisciplinary approach is key to preventing accidents relating to needle sticks, blood-borne infections, injections, fluids, and drugs in paediatric practice.

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