Detection of IV Medicine Mixtures at Low Flows

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Contents

- Background: Intravenous Infusion
- Challenges in Neonatal IV
- IV Mixtures and their Detection
- Future Work

Project Participants

Partners

UNIVERSITY OF TWENTE
Intravenous Infusion

- IV pole
- IV container
- Secondary infusion port
- Infusion pump
- Lower injection port
- Extension tubing (add-on device)
- Multiport connector
- Medial access port
- Distal access port
- Proximal access port
- Peripheral single-lumen catheter
- Peripheral access port
- Central multi-lumen catheter
MAKING SMART PUMPS SMARTER, MAKING IV THERAPY SAFER

Making smart pumps smarter, making IV therapy safer

Insights from the sharp end of intravenous medication errors: implications for infusion pump technology

M Husch, C Sullivan, D Rooney, C Barnard, M Fotis, J Clarke, G Noskin


In 2010 the UK’s National Patient Safety Agency (NPSA, 2010) reported a significant year-on-year increase in the reporting of medication incidents. The agency’s analysis indicated that errors in administration (42%) outweighed the number of errors related to prescribing (32%). Of the reported events that led to serious harm or death, 62% involved IV medicines (Quinn, 2011).

Table 1  Number, frequency, and potential severity of each type of error

<table>
<thead>
<tr>
<th>Type of error</th>
<th>Total (n = 389)</th>
<th>Frequency per medication observations* (n = 426)</th>
<th>NCC MERP severity rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>No rate on label</td>
<td>195</td>
<td>46%</td>
<td>195</td>
</tr>
<tr>
<td>Unauthorized medication</td>
<td>68</td>
<td>16%</td>
<td>65</td>
</tr>
<tr>
<td>Patient identification error</td>
<td>55</td>
<td>13%</td>
<td>55</td>
</tr>
<tr>
<td>Rate deviation</td>
<td>37</td>
<td>9%</td>
<td>29</td>
</tr>
<tr>
<td>Incorrect rate on label</td>
<td>16</td>
<td>4%</td>
<td>16</td>
</tr>
<tr>
<td>Incorrect medication</td>
<td>14</td>
<td>3%</td>
<td>11</td>
</tr>
<tr>
<td>Delay of rate or medication change</td>
<td>4</td>
<td>1%</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>373 (96%)</td>
<td>8 (2%)</td>
<td>5 (1%)</td>
</tr>
</tbody>
</table>

*Percentages in this column do not add to 100 because some medications had more than one error.
Factors Impacting Flow Rate Variability

Patient (age 28 weeks) has mean blood pressure: 25 mmHg. Goal = 28 mmHg

- Start treatment: 0.5 ml/h Dopamine infusion
Causes of Flow Variability in IV Systems

**IV Flow Sources** (pumps)

**Steady-State Errors:**
- Syringepump (Calibration, oscillation)
- Imperfect syringes (Dimensional errors)

**IV Delivery & Mixing** (lines)

**IV Access Points** (catheters)

**Transient Flow Rate Errors:**
- Visco-Elastic System Behaviour
- Internal Dead Volume
**Viscoelastic effects**

**Simple Model:** Syringe – Tube

- **Lower RC time**
- **Flow rate**
- **63%**
- **100%**

**Hospital IV, plastic syringe-rubber tube system: RC time**

Water, $V_{syringe}=100\text{cc}$, tube length is $L$, thick wall approximation

(RC time directly proportional to $V_{syringe}$)

- **No large RC delays?**

**Graph:**
- **RC time** vs. **Tube Inner Radius [µm]**
- Lines for different $L$ values:
  - $L=10\text{cm}$
  - $L=50\text{cm}$
  - $L=150\text{cm}$
  - $L=300\text{cm}$

- **Hospital IV tubing typical inner radius**

- **5min**
- **10s**
- **300µm**
- **1.5mm**
Visco-Elastic System Behavior
Pump interaction is most important

DRUG OVER/UNDER DOSE!

No dead volume

PUMP 1
PUMP 2
PUMP 3

Patient
Internal Volume Effect

In Vivo Study with Epinephrine IV tubing of different internal volumes $V_d$

Drug Infusion System Manifold Dead-Volume Impacts the DelIVERY Response Time to Changes in Infused Medication Doses In Vitro and Also In Vivo in Anesthetized Swine

Mark A. Lovich, MD, PhD,* Matthew G. Wakim, BS,* Abraham Wei, BS,* Michael J. Parker, MD,† Mikhail Y. Maslov, MD, PhD,* Matthew J. Pezone, BA,* Hisashi Tsukada, MD,‡ and Robert A. Peterfreund, MD, PhD§

ANESTHESIA & ANALGESIA

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**In Vivo Study with Noradrenaline (NA)**

IV tubing of different internal volumes $V_d$

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**Figure 3: Influence of infusion devices on mean arterial blood pressure**

Solutions to IV Flow Variability

Hospital Protocols

<table>
<thead>
<tr>
<th>Ziekenhuis</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geprotocollerde activiteit</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apart NICU/Neonatologie-protocol</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niet doorspoelen bij inotropica</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exact aantal ml bij doorspuiten en de inhoud van het systeem staat vast</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Aangeven waar welke medicijnsoorten aangesloten moeten worden op de infusielijn (inotropica zo dicht mogelijk bij patiënt aansluiten)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Volgorde van plaatsen infusiespompen: welke boven, welke onder</td>
<td>-</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volgorde overschakelen van infusiesloestoof, van niet belangrijk naar belangrijk</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spuitpompen voor het overschakelen van tevoren laten lopen</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Bouwt een nieuwe toren met alle nieuwe medicatie naast de oude toren voor dat de medicatie wordt overgeschakeld</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Afsluiten met een kocher</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Accurate IV Administration?

Encapsulate multiple drugs and deliver them digitally as trains of droplets...

Mixture detection at catheter


Protocols exists for many of the observed occurrences, but
- No standard list exists
- Difficult to protocol for adverse flow effects if cause is unknown
Detection of Mixture Properties

Inverse Mixing Matrix

1. Viscosity
2. Thermal Conductivity
4. Density
5. Electrical Conductivity
6. pH
7. Refraction Index
8. Electrical Permittivity
9. …

Sensor
Catheter
IV Mixture
Patient
- Component concentrations
  \( w_i \)

Delta P
Mass Flow
Thermal Flow
(anemometric)
Thermal Flow
(calorimetric)

Inverse Mixing Matrix
Future Work

Active substances are not present pure in IV solutions:
- Indirect Detection of mixtures
- Additives may give greater signal contrast

How are IV solutions prepared in practice?
- Equal pH/osmolarity in each syringe or
- Targeting pH/osmolarity @ specific mixture ratio

Performing inverted mixing model measurements
- Temperature sensing key due to flow-dependent temp. gradients in active devices
Visit our Demo for more ...

Questions?

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