Infusion Evolution: Exploring and Refining a Novel Solution to Provide Rate-Controlled Medication Infusion in Ghana

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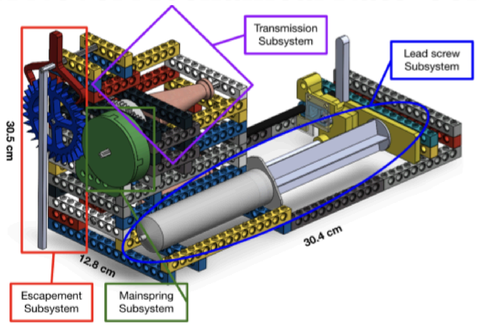
Introduction

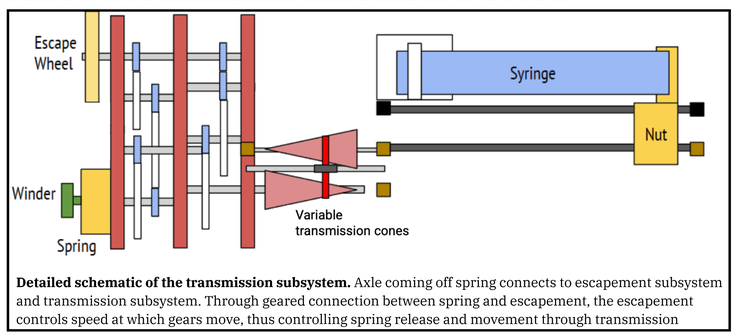
- Rate-controlled intravenous (IV) equipment is crucial in healthcare settings to provide **precise medication dosing and immediate concentration** to patients [1]
- Standard IV equipment is **expensive** and requires availability of **consistent electricity** [2]
- In high-income countries, infusion devices are readily available for all patients; **in low- and middle-income countries (LMICs), including Ghana, there is a lack of access to these critical devices** [3,4]
- Devices designed for high-income countries are often not implemented in LMICs due in part to a **misalignment between currently available solutions and the contextual needs and resources available in resource-constrained health settings** [3,5]

Our Intervention

- We **designed a prototype of a fully mechanical** (does not require electricity), **low-cost** (~150 USD, 79% less costly than the cheapest device on the market currently), **rate-controlled infusion device for the LMIC context** [6]
- Our proof-of-concept prototype can **currently reach infusion rates of 2.7 mL/hr to 6.8 mL/hr** [6]
- With CGHE Seed Grant funds, we are **testing and refining this device**
- We intend to reach the following performance targets: (a) **expanded range of infusion rates** *(1 to 10 mL/hr in increments of 1 mL/hr)*; (b) **constant infusion rates** *(±10% minimally, ±5% optimally)*; (c) **long operation time** *(5 hr minimally, 10 hr optimally)*

A Novel Mechanical Rate-Controlled Medication Infusion Device

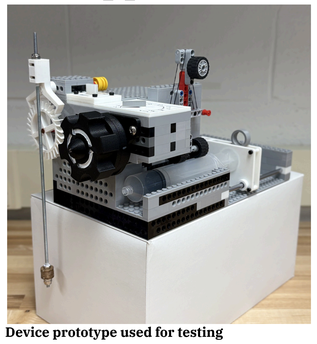




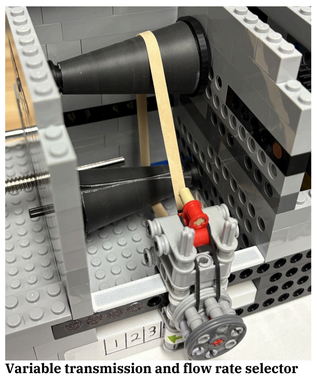
Detailed schematic of the transmission subsystem. Axle coming off spring connects to escapement subsystem and transmission subsystem. Through geared connection between spring and escapement, the escapement controls speed at which gears move, thus controlling spring release and movement through transmission

Initial proof-of-concept prototype. User selects desired infusion rate by selecting a variable gear ratio (*transmission* subsystem). Device is powered by user-wound power spring (*mainspring* subsystem) which transfers motion to *escapement* subsystem; escapement subsystem controls speed at which spring unwinds and transfers motion through transmission which further controls speed of motion transferred to *lead screw* subsystem. Lead screw translates motion linearly to pallet which depresses syringe and administers medication into an IV line [6].

Our Approach to Contextual Iteration



Device prototype used for testing

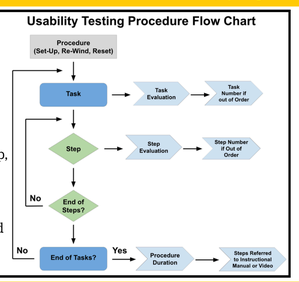


Variable transmission and flow rate selector

1. Evaluate **usability**, **feasibility**, and **acceptability** of device among Ghanaian health care professionals (nurses, midwives, physicians)

Usability testing with nurses and midwives (n~30)
Procedures: device introductions, timed simulation trials, checklist

Usability testing procedure flowchart. After device introduction, nurses and midwives set-up, re-wind, and reset the device. To do so, they complete a series of tasks, or interactions with device subsystems (e.g., "Wind Knob"). Tasks may have multiple sub-steps (e.g., Step 1: "Wind knob counter-clockwise" Step 2: "Use indicator to wind 100%")



Feasibility and acceptability assessment with nurses, midwives, physicians (n~30 nurses & midwives, n~20 physicians)
Procedures: device introductions, semi-structured interviews, surveys

2. Assess **adaptability** of device within clinical workflows

Assessment of how device may fit into clinical workflows (e.g., OBGYN, A&E, ICU, surgery) **with nurses and midwives** (n~30)**, including investigation of existing protocols, resource allocation, and perceived barriers and facilitators to adopting new device**
Procedures: clinical unit observations, nurse and midwife shadowing, semi-structured interviews, focus group discussions

3. Iteratively **refine** device for further testing (preclinical performance)

Redesign transmission *to achieve greater range of infusion rates*	**Tighten system tolerances** *to improve constancy of performance*	**Iterate mainspring and escapement** *to increase time of operation*	**Identify opportunities for further refinement** *based on (1) and (2)*

Future: continue to develop device towards **LMIC implementation** (clinical testing, manufacturing at-scale)

There is a need to **improve access to accurate and reliable IV administration** in LMICs

We designed a **proof-of-concept device** that provides rate-controlled medication infusion **without the use of electricity**

We are currently **testing and refining the device in Ghana**, assessing and enhancing its **usability, feasibility, acceptability, and adaptability** for use in LMIC settings

References: [**1**] Lenz JR, Degnan DD, Hertig JB, Stevenson JG. A Review of Best Practices for Intravenous Push Medication Administration. Journal of Infusion Nursing. 2017;40(6):354-358. [**2**] Thiyagarajan D, Adanu EA, Amico KR. Obstetrics and gynecology devices designed for low- and middle-income countries: A narrative review. Int J Gynaecol Obstet. 2024 Nov 26. [**3**] Compton B, Barash DM, GE Foundation, et al. Access to Medical Devices in Low-Income Countries: Addressing Sustainability Challenges in Medical Device Donations. NAM Perspectives. 2018;8(7). [**4**] Kappler E. *Clinical Needs Assessment in Accident & Emergency Komfo Anokye Teaching Hospital, Kumasi, Ghana*. University of Michigan; 2023. [**5**] Malkin RA. Barriers for medical devices for the developing world. Expert Review of Medical Devices. 2007;4(6):759-763. [**6**] Connolly S, Selle E, Kappler E, Acheampong EK, Thiyagarajan D, Kramer J. A Mechanical Rate-Controlled Electricity-Free Medication Infusion Device for Low- and Middle-Income Countries. Journal of Medical Devices. 2025:1-25.

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