THE HISTORY AND INNOVATION OF VENOUS ACCESS PORTS AND DEVICES

ELIZABETH WONG, CRNA, MSN
LIZWONG6@GMAIL.COM

DISCLOSURES

Elizabeth Wong, CRNA, MSN, is a staff member at
Desert Regional Medical Center
1150 N. Indian Canyon, Palm Springs, CA 92262.
818-620-3692

Elizabeth Wong, CRNA, MSN, is Founder and CEO of DoubleLock Healthcare, Inc, inventor and patent holder of the DoubleLock Sterile Entry Intravenous Port and Syringe System (U.S. Patent #9352141), assignee of the DoubleLock Sterile Entry Intravenous Port and Syringe Interface System (U.S. Patent pending #20240149040). DoubleLock Healthcare, Inc. is a member of the Global Engineered Device Supplier Association and Elizabeth Wong serves on six GEDSA committees that include Neuraxial (NRFit®) Member Committee, Enteral (ENFit®) Member Committee, Neuraxial (NRFit®) Conversion Committee, Enteral (ENFit®) Conversion Committee, Supply Chain and Clinical Advisory Committee, Neuraxial (NRFit®) and Enteral (ENFit®) Joint Member Committee; and DoubleLock Healthcare, Inc. is a member of the Association for the Advancement of Medical Instrumentation) (AAMI) which is the U. S. representative to the International Organization for Standardization (ISO) and Elizabeth Wong serves on the Standards Development Committees for Syringes ISO 7886 Series and the Small Bore Connectors ISO 80369 Series.

1995 -STUDENTS OF THE USC PROGRAM OF NURSE ANESTHESIA

1995 -STUDENTS OF THE USC PROGRAM OF NURSE ANESTHESIA

California Association of Nurse Anesthesiology - 2010

Learning Objectives

1. Discuss the history of medical devices that include needles, syringes, and IV ports

2. Describe why medical device innovation takes place

3. Explain the process and resources for developing a medical device

4. Contrast the difference between a regulatory / enforcement agency, a standard-developing organization, and a trade association

The Beginning of the Journey

Lecture in 2010, AANA Conference - Anesthesia and Infection Control

Chuck Biddle, PhD, CRNA

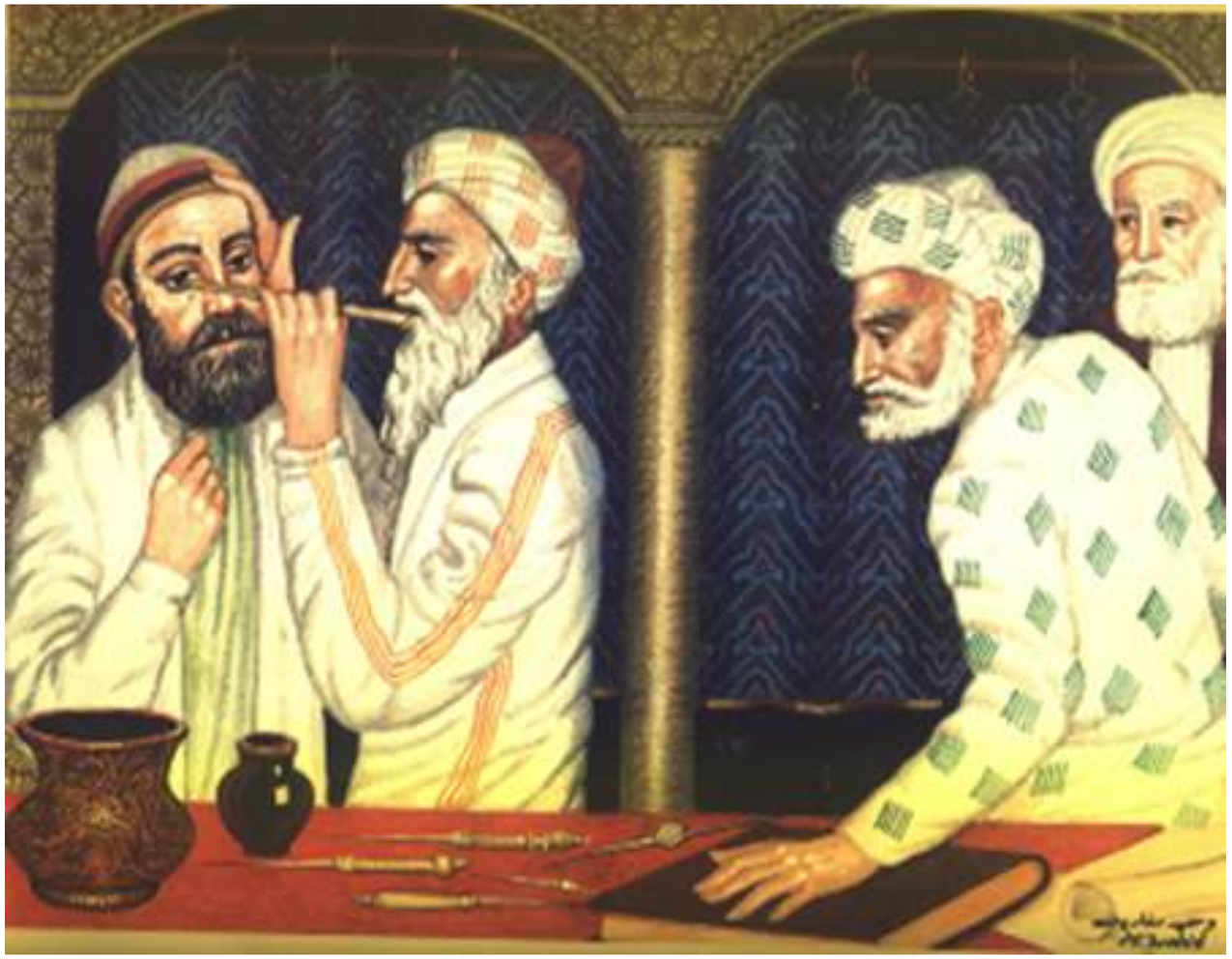
Director of Research
Virginia Commonwealth University
Editor of the AANA Journal (now retired)

History of the Needle

World's oldest needle, at least 50,000 years old, found in the Denisova cave, Siberia, made of bone that “stitches” together human history.

Images from Siberian Times article free to share and use.

History of the Syringe



The first recorded use of a needle and syringe was in the 9th century, when an Arabian physician named Ammar bin Ali al-Mawsili, used a glass tube needle and syringe to extract a cataract from a patient.

Image from is 800 years old and no longer copyright protected according to , Helena P. Schrader, Historian and Novelist, helenapschrader.com

IV Therapy - Wine, Ale, Opium

Christopher Wren (1632-1723) conducted the first successful IV therapy in 1658 by using a **goose quill needle** and **pig's bladder** to infuse a mixture of wine, ale, and opium into a dog's veins. "The dog tolerated it remarkably well."

Image: Courtesy Wikigallery Free to Use and Share

1820s - THE TURNING POINT

Image of Needle Free to Use and Share

STEEL was discovered!!

NEEDLES DISTRICT - ENGLAND:

- **1820 - 5 million needles per week**
- **1850 - 50 million needles per week**

Francis Rynd (1860-1861) an Irish physician took a steel sewing needle, flattened it, formed it into a tube, and clipped off the eye. He invented the hollow needle used for hypodermic injection in 1844

Image of Francis Rynd Free to Use and Share

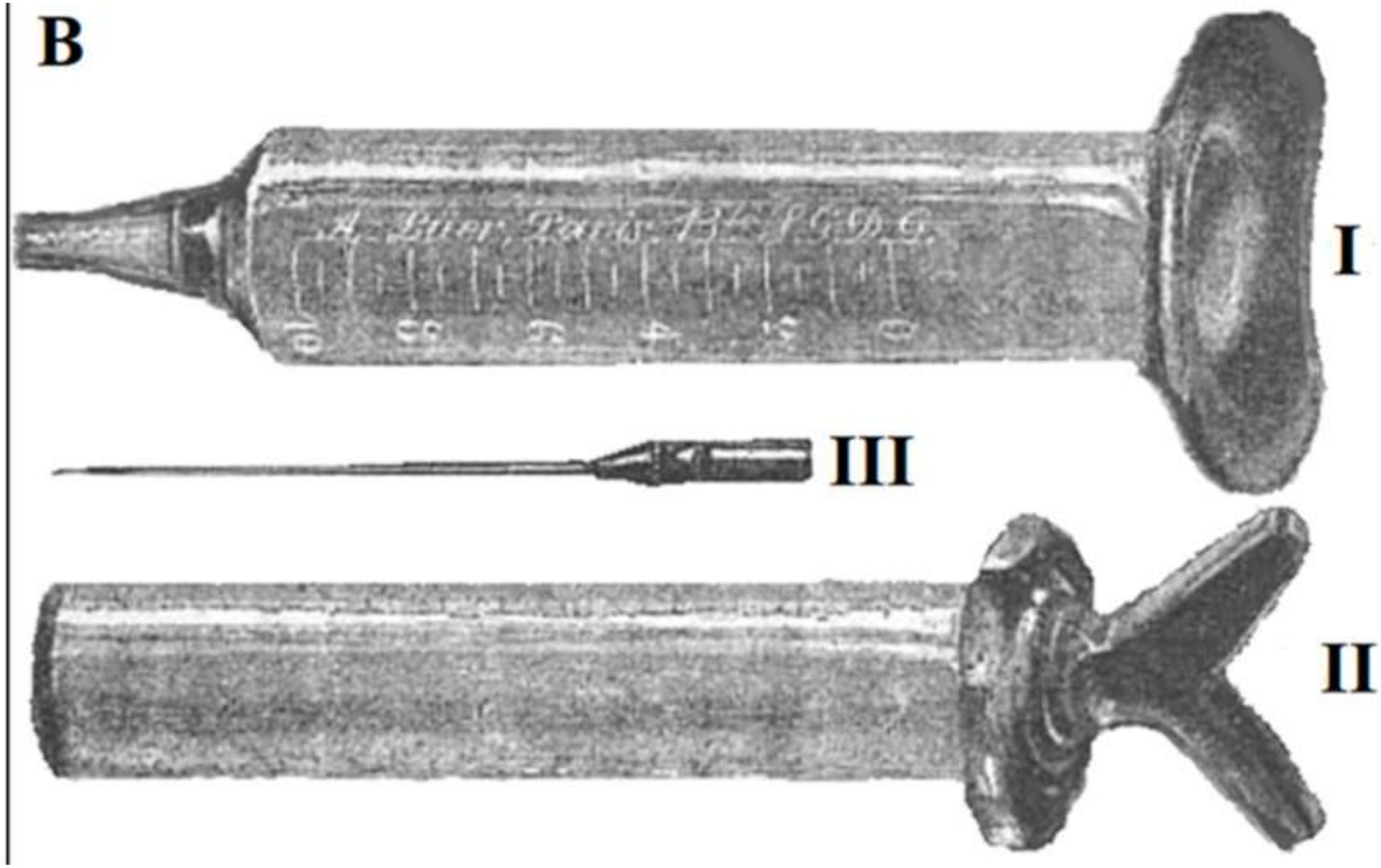
Fig. 4. — A Pravaz-type syringe, made of glass and silver

DOUBLE LOCK HEALTHCARE, INC.

Charles Gabriel Pravaz (1791-1853)

Glass Syringe, Silver Hypodermic Needle, Cage and Screw Plunger created in 1853.

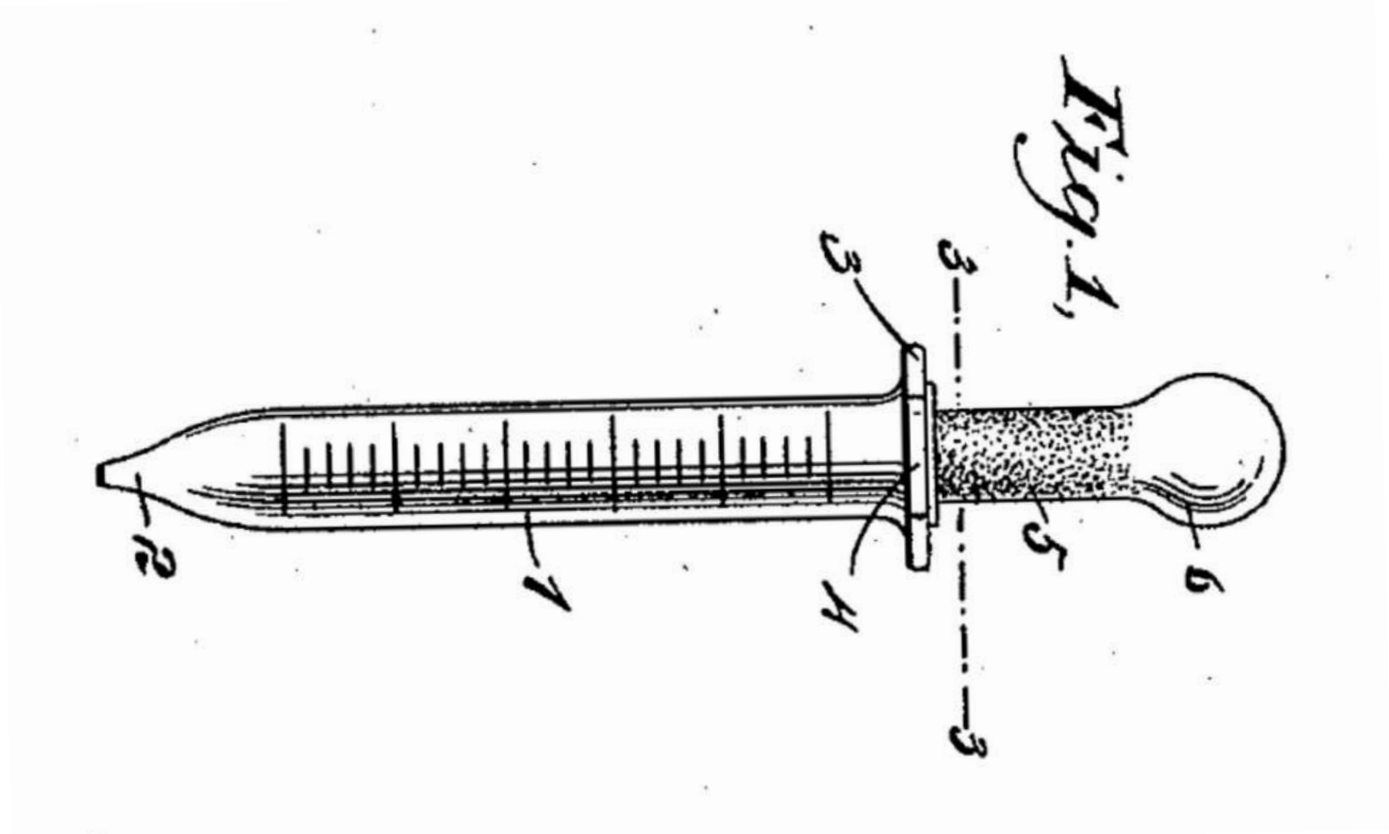
Image of Charles Gabriel Pravaz and Syringe Free to Use and Share



Georges Guillaume Amatus Lüer (1802–1883)

All glass syringe, detachable needle, sliding plunger created in 1860

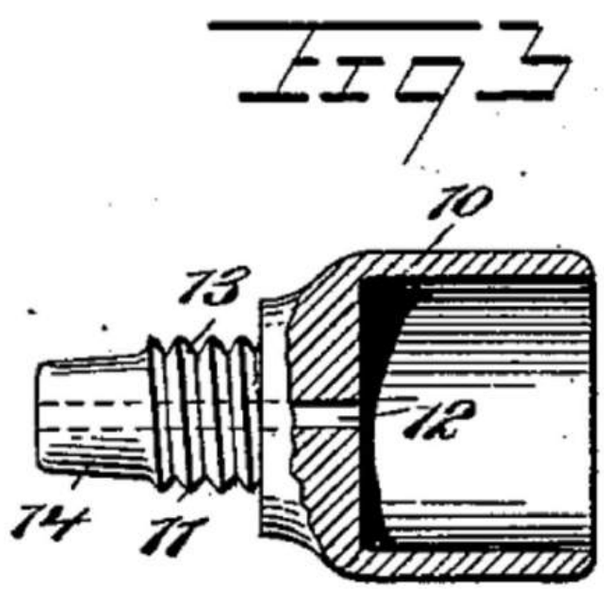
Image of Luer Syringe Free to Use and Share



Hermann Wulfing-Lüer (business manager and son-in-law). Syringe. U. S. Patent 583,382. Application filed December, 11, 1896. Image courtesy of the United States Patent and Trademark Office.

THE PROBLEM

Needles are not secure and pop off when a drug is forcefully injected

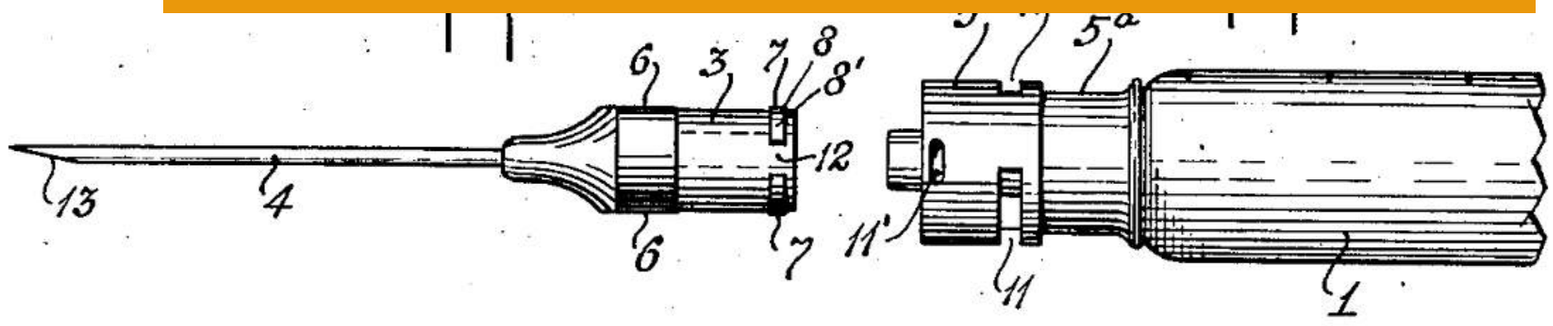


Fairleigh S. Dickinson.
Hypodermic Syringe.
U. S. Patent 723,588.
Application filed
January 15, 1901. Image courtesy of the United States Patent and Trademark Office.

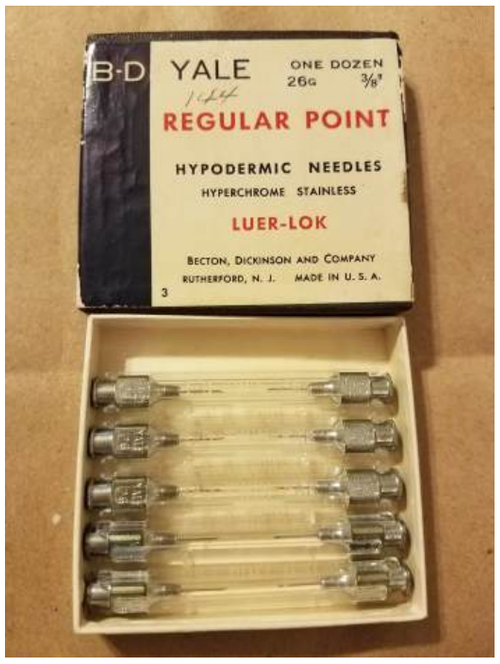
THE PROBLEM

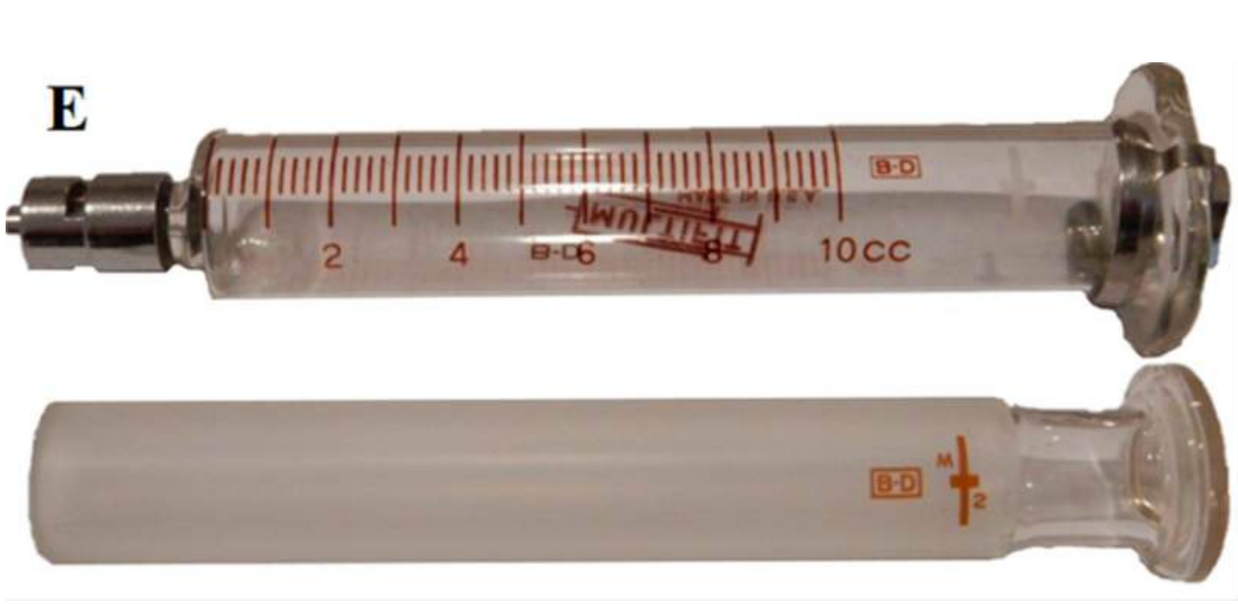
Threads are too fine.
Needles are not secure and pop off when a drug is forcefully injected

THE LüER-LOK



Fairleigh S. Dickinson. Syringe. U. S. Patent 1,793,068. Application filed January 6, 1930. Image courtesy of the United States Patent and Trademark Office.





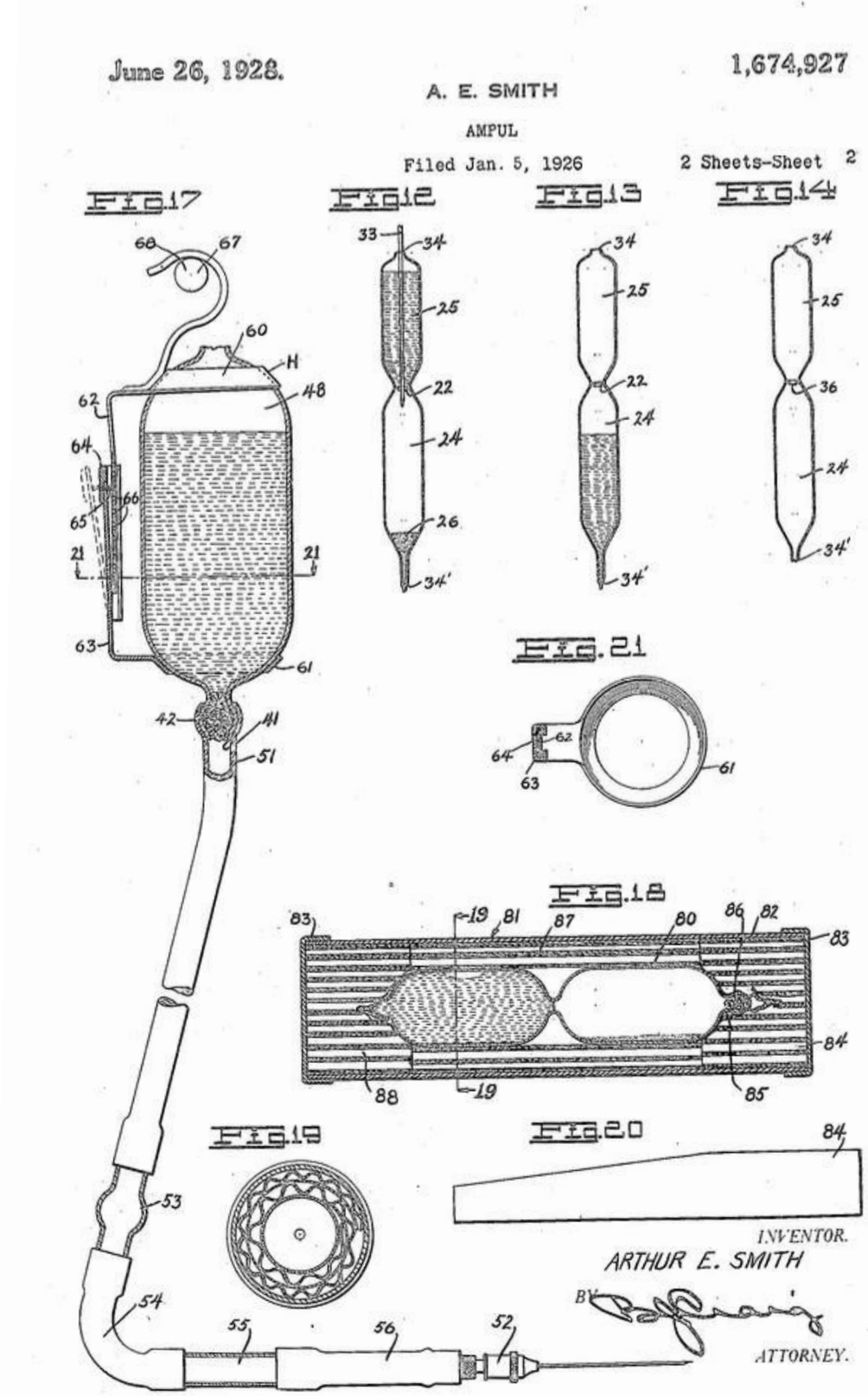
Only change since 1930 is material used; disposable glass in 1940 and disposable plastic in 1960. Luer-Lock connectors are used in 6 physiological systems: respiratory gas, enteral, neuraxial, urinary, limb cuff, and intravascular.

Image of Syringe Free to Use and Share Image of Needles courtesy of Zane Antiques.

The Problem: Syringe Tip Contamination

Microbial contamination of syringes during preparation: The direct influence of environmental cleanliness and risk manipulations on end-product quality

Microbial contamination of anesthetic syringes in relation to different handling habits


June 26, 1928. 1,674,927

A. E. SMITH

AMPUL

Filed Jan. 5, 1926 2 Sheets-Sheet 2

Fig. 17

Fig. 12

Fig. 13

Fig. 14

Fig. 21

Fig. 18

Fig. 19

Fig. 20

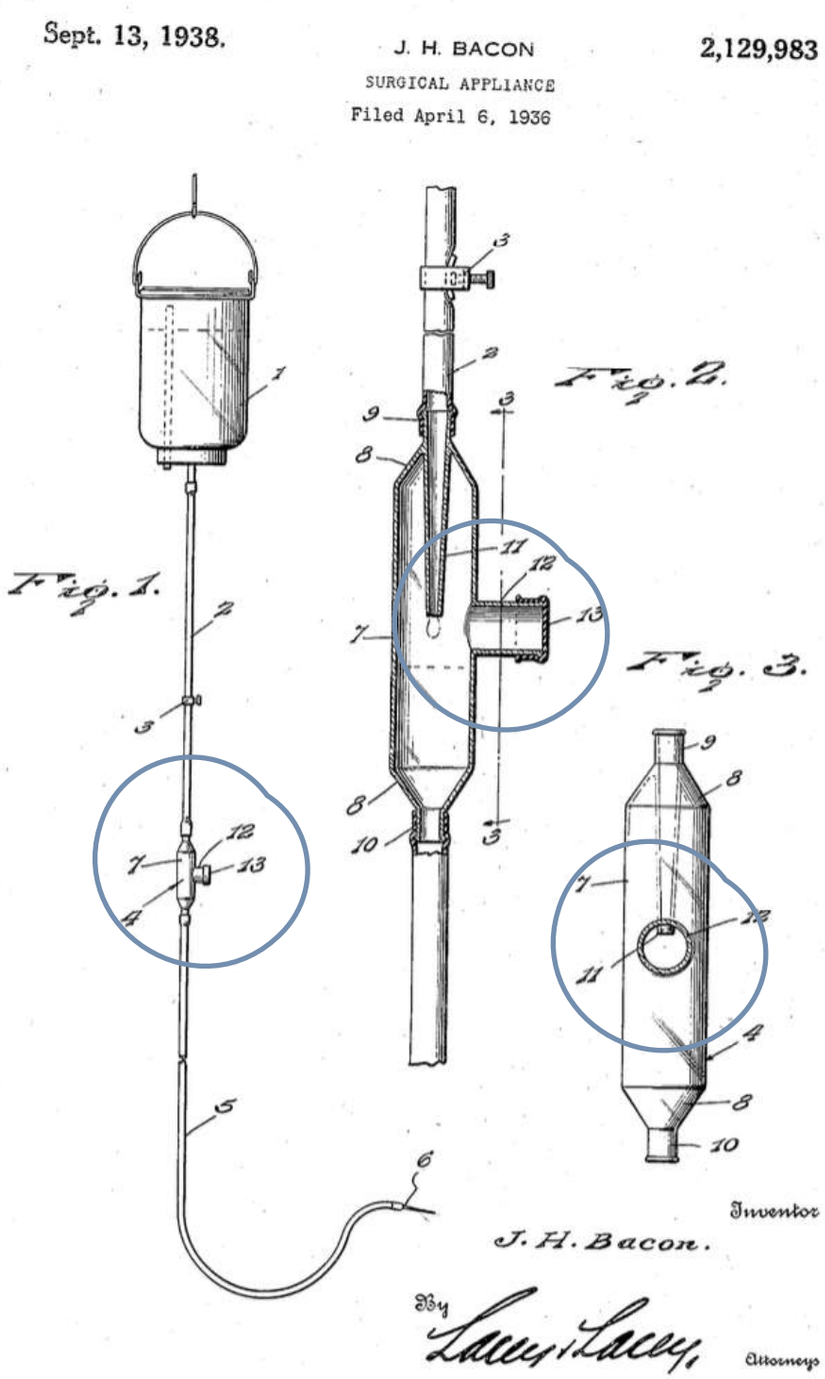
INVENTOR.
ARTHUR E. SMITH
BY
ATTORNEY.

Arthur E. Smith. Ampul
Patent 1,674,927
filed January 25, 1926. Image courtesy United States Patent and Trademark Office.

Drug in clear area.
Solution in hashed area.
Needle enters from above and pierces the thin membrane.
The drug and solution mixes.
The tubing is made of rubber or plastic permitting the fluid to flow through the hypodermic needle into the vein.

THE PROBLEM

No IV Ports


Sept. 13, 1938. J. H. BACON 2,129,983

SURGICAL APPLIANCE

Filed April 6, 1936

Fig. 1.

Fig. 2.

Fig. 3.

Inventor

J. H. Bacon.

By Lacey & Lacey, Attorneys

Jay Harvey Bacon. Surgical Appliance. Patent 2,129.983. Filed April 6, 1936.

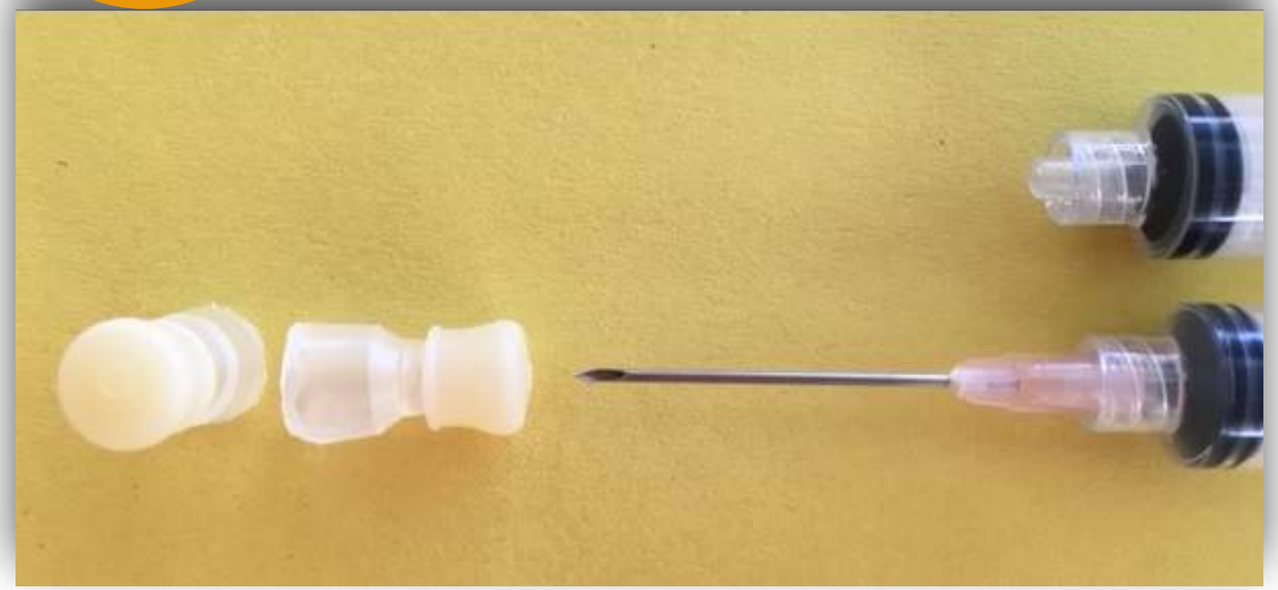
Image Courtesy of the United States Patent and Trademark Office.

RUBBER STOPPER IV PORTS

1st Generation

Rubber Stopper IV Port

1st Generation



(1991)

FDA Issues Safety Alert for Hypodermic Needles on Secondary IV Administration Sets

(1992)

. Chlarello L. Testimony on needlestick prevention technology. Presented before US Congress Committee on Small Business, Subcommittee on Regulation, Business Opportunities, and Energy. Washington, DC; February 7, 1992.

THE PROBLEM

NEEDLE-STICK INJURY

(1993)

The use of needles in the practice of anesthesiology and the effect of a needle-less intravenous administration system. Berry AJ. Anesth Analg. 1993. PMID: 8484516

Y-TYPE OPEN LUMEN LUER-LOCK IV PORT CONNECTOR - 1951

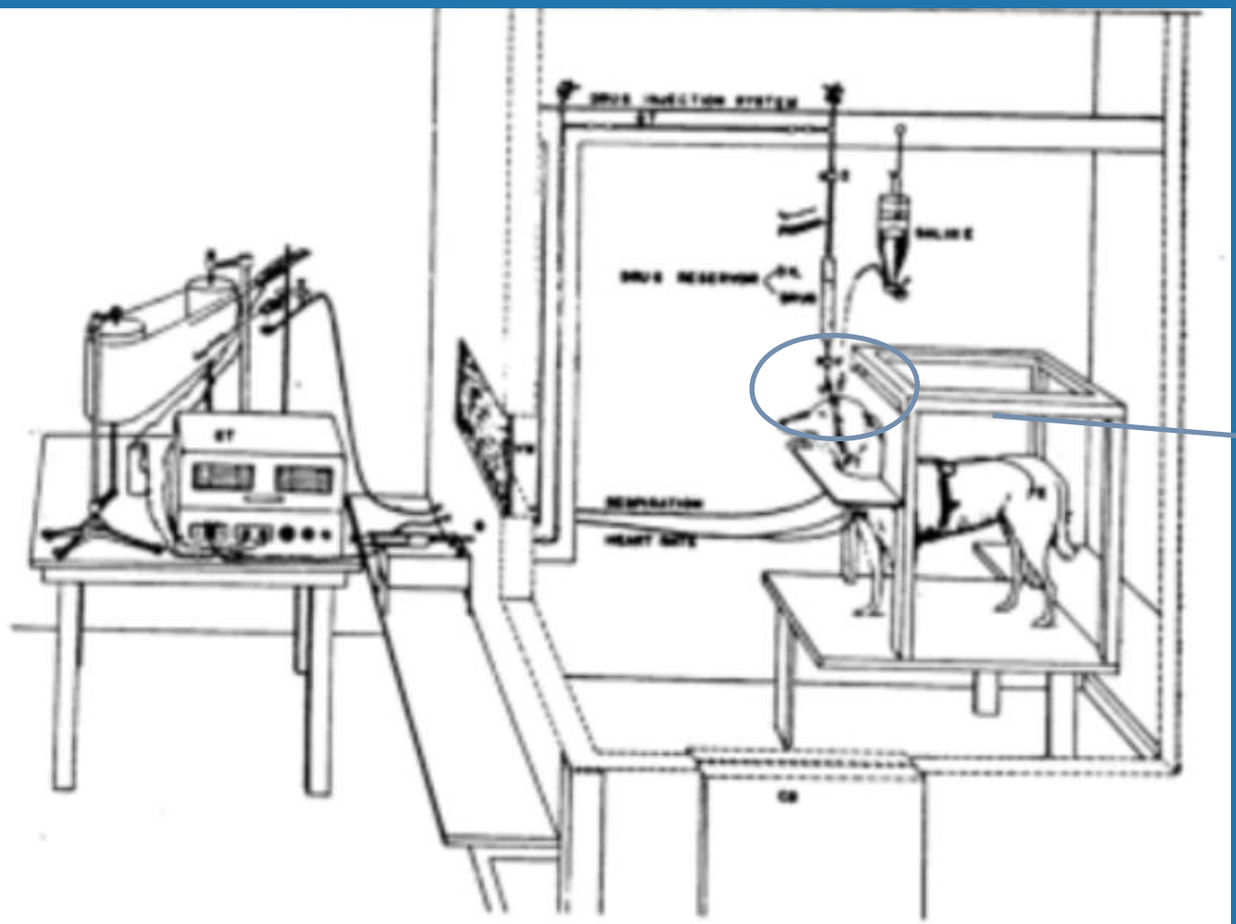


FIG. 1. Arrangement of injection apparatus and dog during experiment: *E*, electrodes for heart rate; *P*, pneumograph; *PT*, plastic (polyethylene) tubing; *T*, Y-tube; *GT*, oil-filled glass tubing; *CT*, cardiotachometer; *CD*, camera door; *O*, outlet for oil-filled tubing; *VW*, viewing window—one-way vision from outside camera; 1, 2, and 3, stopcocks.

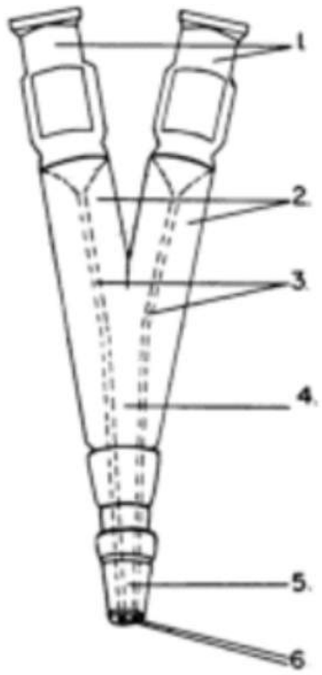


FIG. 2. Y-tube showing details of construction: 1, adapters of arms; 2, arms of Y-tube; 3, inner tubes; 4, stem of Y-tube; 5, adapter; and 6, open ends of inner tubes.

Image Courtesy of the American Association for the Advancement of Science

2nd Generation

THE PROBLEM

Bacteria Transmission

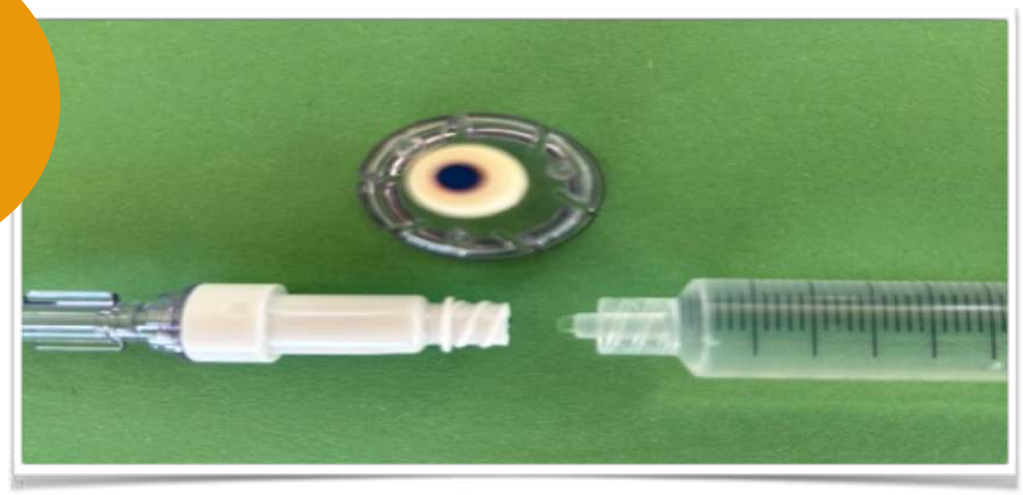
Open-Lumen Luer-Lock IV Port

Muffly et al.

- Open Lumen - open portal for bacteria
- No surface area to disinfect
- Greater incidence of drug staying in the dead-space of the ports
- Increased incidence of microbial growth in dead-space
- Associated with increase in morbidity and mortality

CLOSED-LUMEN LUER-LOCK IV PORTS

3rd Generation



needle-less IV port & syringe
= exposed, large surface area, easily contaminated with bacteria.

(1990-1993)

POSTOPERATIVE INFECTIONS TRACED TO CONTAMINATION OF AN INTRAVENOUS ANESTHETIC, PROPOFOL

(1993)

Use of Disinfectants To Reduce Microbial Contamination of Hubs of Vascular Catheters

THE PROBLEM #1

(1995)

Relevance of the Catheter Hub as a Portal for Microorganisms Causing Catheter-Related Bloodstream Infections

Bacteria Transmission

PROTECT THE IV PORT!
(After Market Treatments)

Wipe IV Port with an alcohol swab and wait 30 seconds for the IV Port to dry prior to every access

Manufacturer's Recommended IV Port Treatment = Hospital Policy

IV Port Asepsis Compliance

Infection prevention in the operating room anesthesia work area

Munoz et al.
- "<<20% of providers comply with IV port asepsis"

Review Article

Disinfection of Needleless Connector Hubs: Clinical Evidence Systematic Review

Moureau and Flynn
- "Compliance with IV port asepsis is 10%"

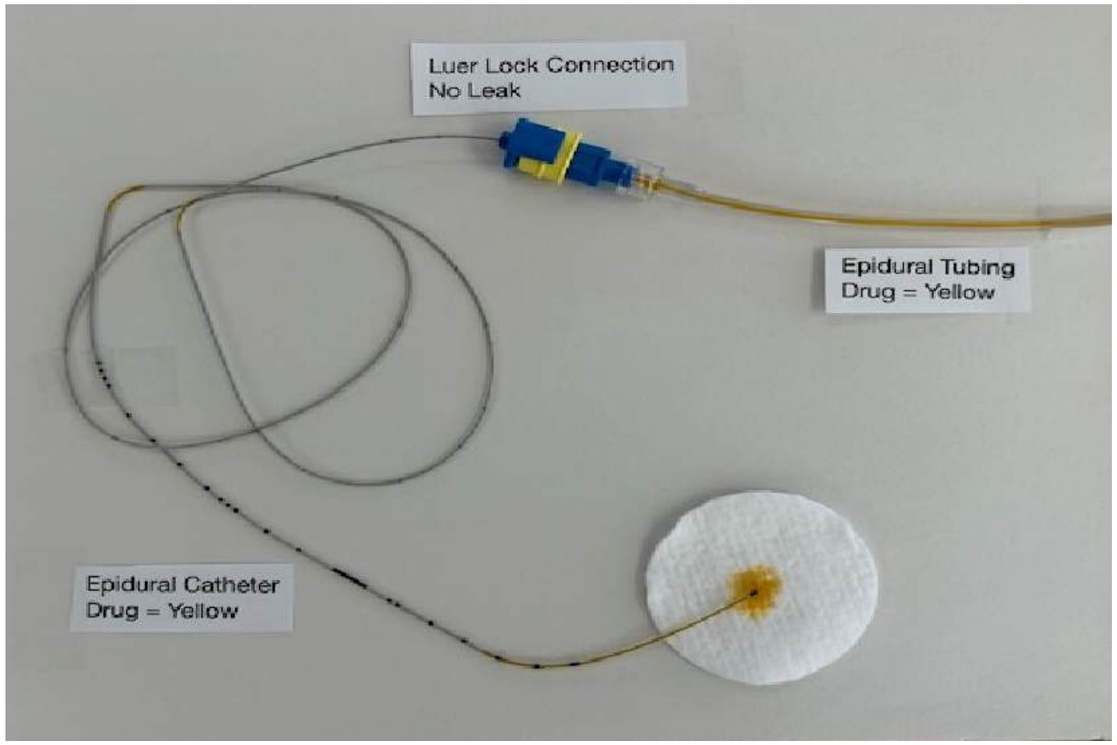
THE PROBLEM #1 **Low compliance**

PROTECT THE IV PORT!
(After-Market Protection and Treatments)

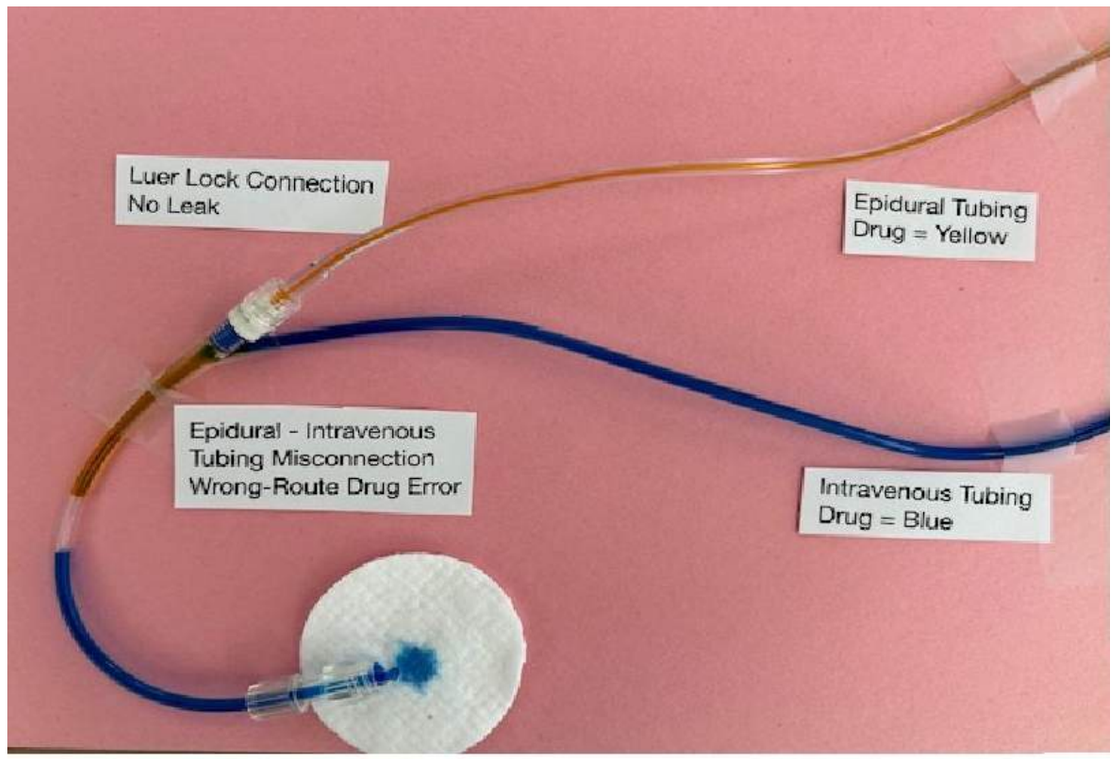
Images Free to Share and Use. Image of Anesthesia Machine drape courtesy C. Biddle.

THE PROBLEM #2

TUBING MISCONNECTIONS AND WRONG-ROUTE INFUSION DRUG ERRORS



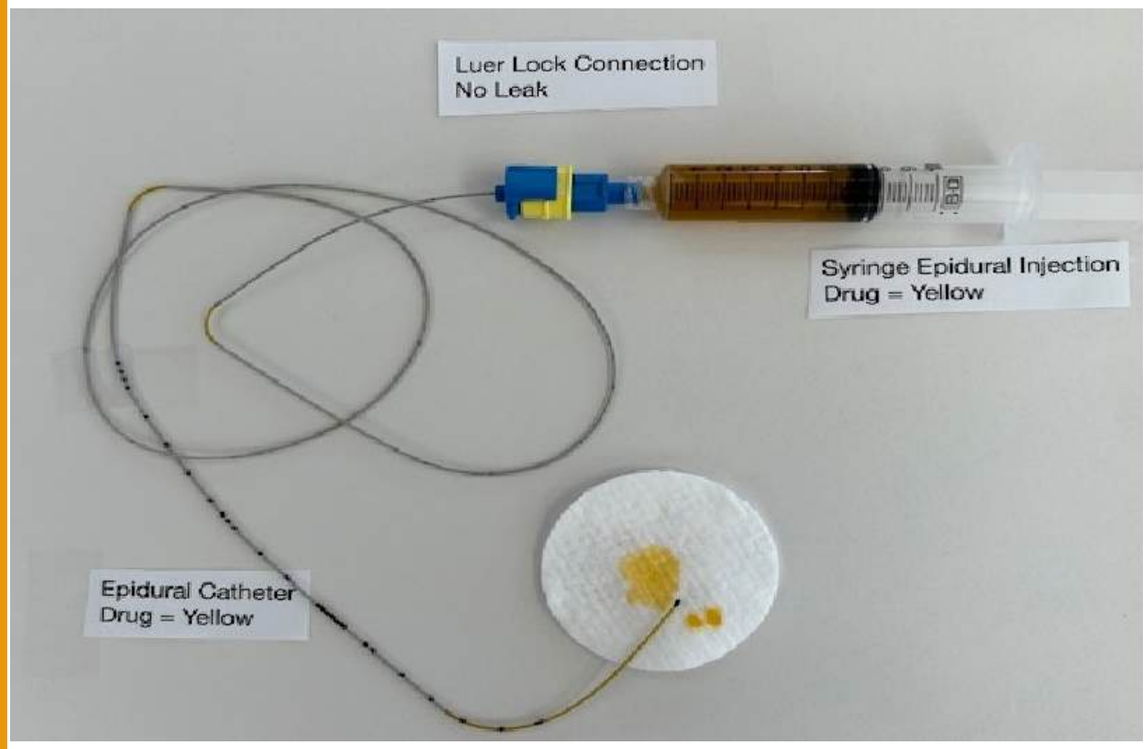
Epidural tubing connected to an epidural catheter. (Epidural drug is dyed yellow for easier visualization).



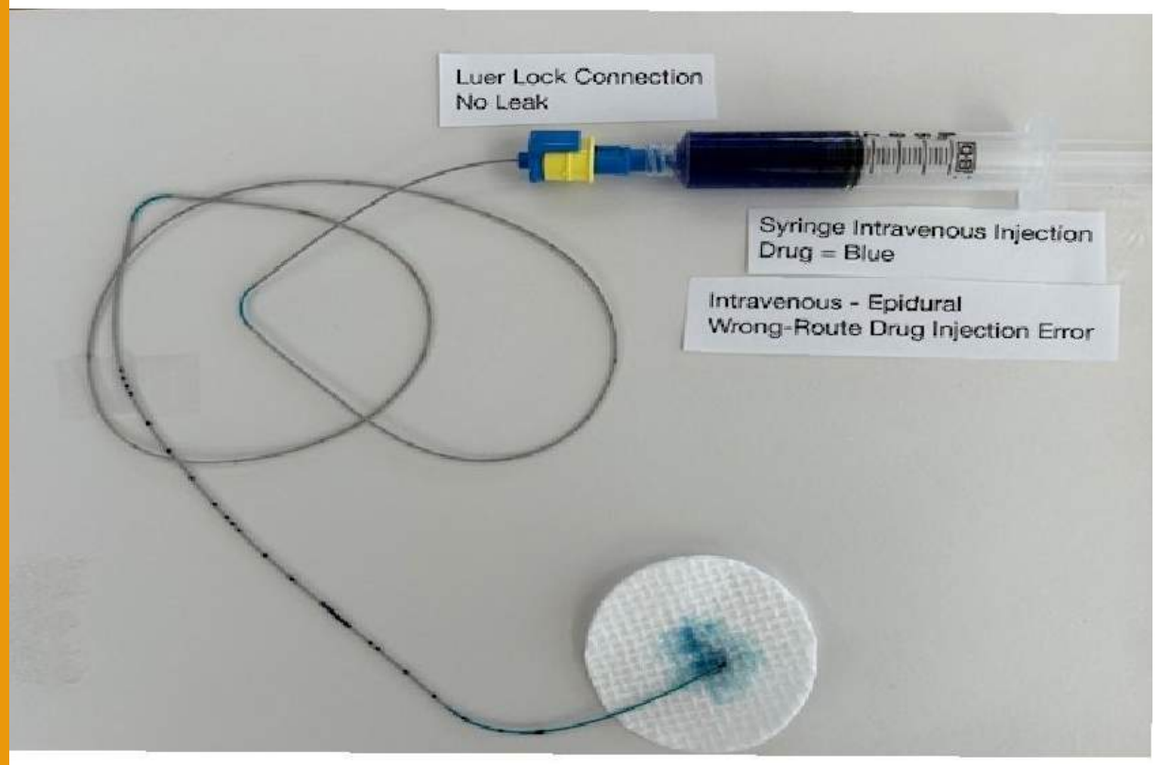
The epidural tubing (epidural drug dyed yellow for easier visualization) is connected to an IV port embedded in IV tubing (IV drug dyed blue for easier visualization).

THE PROBLEM #2

TUBING MISCONNECTIONS AND WRONG-ROUTE INJECTION DRUG ERRORS



An epidural bolus injection of drug (yellow dye) into the open-lumen luer-lock connector in an epidural catheter.



An intravenous bolus injection of drug (blue dye) into the open-lumen luer-lock connector in an epidural catheter.

The
FRONTLINE CLINICAL PROVIDER'S LAMENT

Why doesn't "someone" just create a cleaner, faster, safer IV port and syringe that aims to prevent a source of healthcare-associated infections, tubing misconnections, and wrong-route infusion or injection drug errors?

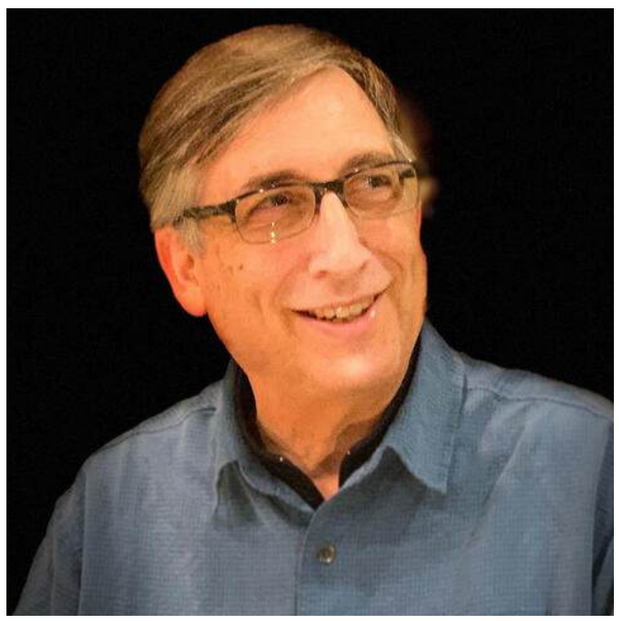
Coachella Valley Economic Partnership
Start-Up Incubator Program

Joe Wallace, CEO

1. Goal is to incite vision-driven transformation
2. Guidance
3. Counseling
4. Resources
5. Networking

DoubleLock Healthcare, Inc. is a member of CVEP since 2018.

National Science Foundation
Innovation Corp Program at U. C. Riverside



1. **Business Plan**
2. **Market Research Plan**
3. **Customer / Problem Discovery Interviews**
4. **Commercialization Plan**
5. **Laboratory space**
6. **Lectures**
7. **Grant writing support**

UC Riverside

NSF I-Corps Program

Liaison: Jay Gilberg

DoubleLock Healthcare, Inc. participated in the iCorp Program in 2022.

THE SOLUTION

DOUBLELOCK Sterile Entry IV Port and Syringe System

Redefining IV Drug Delivery
Proof-of-Concept Prototype

Not FDA Cleared or Approved yet

Value Proposition

- No aftermarket treatment needed
- Eliminates needle-stick injuries
- Unique Connector (ISO 80369) to prevent tubing misconnections
- Prevents bacteria transmission via IV ports
- Prohibits drug leakage
- Provides 100% compliance with IV port & syringe tip asepsis

4th Generation

The DoubleLock Sterile Entry IV Port and Syringe System

+

DoubleLock Healthcare Family of Products

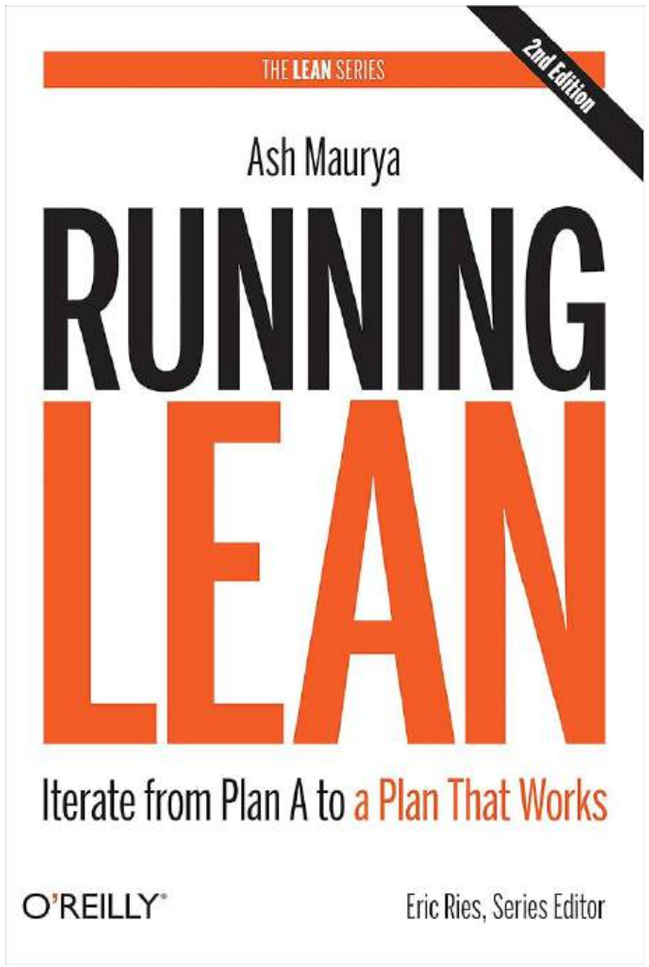
=

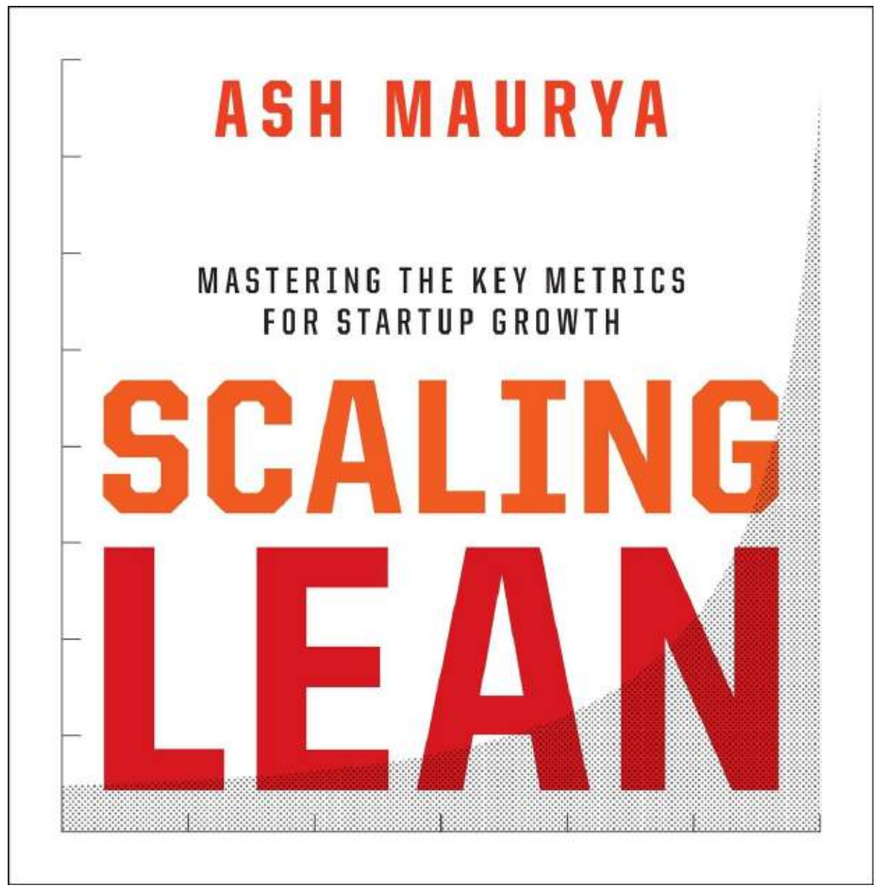
AIMS TO BE THE NEW STANDARD-OF-CARE IN IV DRUG DELIVERY

Images Free to Share and Use.

Mass Challenge
Start-Up Accelerator Program

MassChallenge is the global network for innovators working to solve massive challenges.





Our mission is to equip bold entrepreneurs to disrupt the status quo and to create meaningful change.

DoubleLock Healthcare, Inc. participated in MassChallenge in 2023.

STANDARD DEVELOPING ORGANIZATIONS

Association for the Advancement of Medical Instrumentation (AAMI) - U. S. National

International Organization for Standardization (ISO)
International organization comprised of 171 National Organizations

Global Engineered Device Supplier Association

serves as the bridge between standard-developing organizations, manufacturers, distributors, suppliers, professional organizations, and healthcare facilities to implement ISO 80369 standards.

AANA Convention
San Diego, 2024
(L-R)
Elizabeth Wong, CRNA
Madison Webb, Exec. Asst
Ben Davis, ED & CEO

REVIEW

1. Discussed the history of medical devices that include needles, syringes, and IV ports

2. Described why medical device innovation takes place (based on need, and verbal or research based-feedback)

3. Explained the process of developing a medical device; recognition of a problem, idea generation, research, start-up incubators, accelerators, networking, acquiring resources, joining relevant organizations (AAMI, ISO, GEDSA), prototyping, and testing

4. Contrasted the difference between a regulatory / enforcement agency (U.S. - FDA), a standard-developing organization (U. S.- AAMI and international ISO), and a trade association (GEDSA)

References

History of the Needle

1. World's oldest needle found in Siberian cave that stitches together human history. Siberian Times Reporter. August 23, 2016. http://www.siberiantimes.com/science/casestudy/news/n0711-worlds-oldest-needle-found-in-siberian-cave-that-stitches-together-human-history/. Accessed 8-20-2023.
2. Who Invented the Syringe Needle. Bellis, M. Updated March 3, 2019. https://www.thoughtco.com/who-invented-the-hypodermic-needle-4075653. Accessed 8-20-2023.
3. The History of the Needle and Syringe. Excel Medical. January 8, 2023. https://www.excel-medical.com/the-history-of-the-syringe/. Accessed 8-21-2023.
4. On the history of injection. Svend Norn, Poul R Kruse, Edith Kruse. Dan Medicinhist Arbog. 2006;34:104-13. PMID: 17526154
5. History of injections. Pictures from the history of otorhinolaryngology highlighted by exhibits of the German History of Medicine Museum in Ingolstadt. H Feldmann. Laryngorhinootologie. 2000 Apr;79(4):239-46. PMID: 10838689

History of the Syringe

Mittwoch, E., "ʿAmmār al-Mawṣilī", in: Encyclopaedia of Islam, Second Edition, Edited by: P. Bearman, Th. Bianquis, C.E. Bosworth, E. van Donzel, W.P. Heinrichs. Consulted online on 03 September 2023 <http://dx.doi.org/10.1163/1573-3912_islam_SIM_0628>. First published online: 2012
First print edition: ISBN: 9789004161214, 1960-2007.

2. Ammar bin Ali al-Mawsilli. https://muslimheritage.com/people/scholars/al-mawsili/ Accessed 8-8-2023

IV Therapy

1. The history of peripheral intravenous catheters: how little plastic tubes revolutionized medicine. A M Rivera, K W Strauss, A van Zundert, E Mortier. Acta Anaesthesiol Belg. 2005;56(3):271-82. PMID: 16265830
2. Image: https://www.gettyimages.com/detail/news-photo/sir-christopher-wren-english-architect-c1680-christopher-news-photo/654314494. Accessed 8-8-2023.

1820s- A Turning Point

1. History and Description of Needle Making, Morrall, M. T., Balmoral House, Manchester, 1862.
2. The Story of Iron and Steel, Smith, J. R., D. Appleton and Company, New York. 1909.
3. The History of the Needle and Syringe. Excel Medical. January 8, 2023. https://www.excel-medical.com/the-history-of-the-syringe/. Accessed 8-21-2023.

Francis Rynd

1. A History of Syringes and Needles. Craig, R, Marsh Hirshfield Museum of Medical History. https://medicine.uq.edu.au/blog/2018/12/history-syringes-and-needles. Accessed 8-21-2023.
2. Francis Rynd (1801-1861). No Authors Listed. JAMA. 1970 May 18;212(7):1208. PMID: 4909825

Charles Gabriel Pravaz

1. History of injections. Pictures from the history of otorhinolaryngology highlighted by exhibits of the German History of Medicine Museum in Ingolstad. H Feldmann. Laryngorhinootologie. 2000 Apr;79(4):239-46. PMID: 10838689
2. The history of peripheral intravenous catheters: how little plastic tubes revolutionized medicine. A M Rivera, K W Strauss, A van Zundert, E Mortier. Acta Anaesthesiol Belg. 2005;56(3):271-82. PMID: 16265830

Georges Guillaume Amatus Lüer (1802–1883)

1.Lüer's syringe: an innovation that launched a family empire. Chemistry world. Sella, A.. August 27, 2012. https://www.chemistryworld.com/opinion/luers-syringe/5373.article Accessed 8-21-2023
2. The all-glass Lüer syringe: Historical facts around concepts, introduction and patents. F. Wiepking, A. Van Zundert, J. P. Martin, J. B. Cazalaa and R. Buttner. Anaesth Crit Care Pain Med 2021 Vol. 40 Issue 4 Pages 100921. Accession Number: 34197975 DOI: 10.1016/j.accpm.2021.100921

The Luer-Lock

.Lüer's syringe: an innovation that launched a family empire. Chemistry world. Sella, A.. August 27, 2012. https://www.chemistryworld.com/opinion/luers-syringe/5373.article Accessed 8-21-2023
2. The all-glass Lüer syringe: Historical facts around concepts, introduction and patents. F. Wiepking, A. Van Zundert, J. P. Martin, J. B. Cazalaa and R. Buttner. Anaesth Crit Care Pain Med 2021 Vol. 40 Issue 4 Pages 100921. Accession Number: 34197975 DOI: 10.1016/j.accpm.2021.100921

References

Syringe Tip Contamination

1. Microbial contamination of syringes during preparation: the direct influence of environmental cleanliness and risk manipulations on end-product quality. Stucki C, et al. Am J Health Syst Pharm. 2009. PMID: 19890087
2. Microbial contamination of anesthetic syringes in relation to different handling habits. Florian Heid, Carolin Bender, Hendrik Gervais, Joachim Schmeck, Wolfgang Kohnen, Rüdiger Noppens. Am J Infect Control. 2016 Mar 1;44(3):e15-7. Epub 2015 Nov 7. PMID: 26559736

Rubber Stopper IV port

1. 510K. FDA.gov. K770744. IV set that reverts to KVO Rate. Decision Date 5-26-1977. Substantially Equivalent. Assigned to Abbott laboratories. One Abbott Park Road. Abbott Park, Il. 60064. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfPMN/pmn.cfm?ID=K770744. Accessed 8-26-2023.
2. FDA.gov. Food and Drug Modernization Act enacted in 1997 regulating medical devices. https://www.fda.gov/regulatory-information/selected-amendments-fdc-act/food-and-drug-administration-modernization-act-fdama-1997. Accessed 8-26-2023.
3. FDA issues safety alert for hypodermic needles on secondary i.v. administration sets. No authors listed. Infect Control Hosp Epidemiol. 1992 Jun;13(6):373. PMID: 1619273
4. The use of needles in the practice of anesthesiology and the effect of a needleless intravenous administration system. A J Berry. Anesth Analg. 1993 May;76(5):1114-9. PMID: 8484516
5. Needlesafe versus needleless intravenous injections. Kempen PM. AANA J. 1994 Aug;62(4):308-9. PMID: 7810281
6. Industry has not eliminated needlestick injury: is it time for personal or federal intervention, or both. Kempen PM. Infect Control Hosp Epidemiol. 1996 Apr;17(4):209-11. doi: 10.1086/647279. PMID: 8935726
7. Reducing the incidence of needlestick injuries. P Russell. Prof Nurs. 1997 Jan;12(4):275-7. PMID: 9128678

Y-Type OpenLumen IV Port

A method of intravenous injection of drugs from a distance in conditional reflex studies. TEITELBAUM HA, GANTT WH. Science. 1951 May 25;113(2943):603-5. PMID: 14845680

2. Y-Type Connector. https://us.bbraunoem.com/en/products/b/oem-us-y-connectors.html

Open Lumen IV Ports

1. Prevention of intravenous bacterial injection from health care provider hands: the importance of catheter design and handling. Anesth Analg. 2012 Nov;115(5):1109-19. Anesth Analg. 2012 Nov;115(5):1109-19. Loftus RW, Patel HM, Huysman BC, Kispert DP, Koff MD, Gallagher JD, Jensen JT, Rowlands J, Reddy S, Dodds TM, Yeager MP, Ruoff KL, Surgenor SD, Brown JR. PMID: 23051883
2. Reduction in intraoperative bacterial contamination of peripheral intravenous tubing through the use of a passive catheter care system. Anesth Analg. 2012 Dec;115(6):1315-23. doi: 10.1213/ANE.0b013e31826d2aa4. Epub 2012 Nov 9. Loftus RW, Brindeiro BS, Kispert DP, Patel HM, Koff MD, Jensen JT, Dodds TM, Yeager MP, Ruoff KL, Gallagher JD, Beach ML, Brown JR. PMID: 23144441
3. Stopcock lumen contamination does not reflect the full burden of bacterial intravenous tubing contamination: analysis using a novel injection port. Muffly MK, et al. Am J Infect Control. 2010. PMID: 20630618
4. Stopcock contamination: the source does not explain it all. Zingg W, et al. Anesth Analg. 2012. PMID: 22615441
5. Leaving More Than Your Fingerprint on the Intravenous Line: A Prospective Study on Propofol Anesthesia and Implications of Stopcock Contamination. Cole, DC., Basianti, TO., Granvenstein, NL., Gravenstein, N. Anesth Analg. 2015 Apr;120(4):861-7. PMID: 23749446

References

Closed Lumen IV Ports

1. Postoperative infections traced to contamination of an intravenous anesthetic, propofol. S N Bennett, M M McNeil, L A Bland, M J Arduino, M E Villarino, D M Perrotta, D R Burwen, S F Welbel, D A Pegues, L Stroud, et al. N Engl J Med. 1995 Jul 20;333(3):147-54. PMID: 7791816

1990 - 1993 Seven hospitals had an outbreak of bloodstream infections, surgical site infections, and acute febrile episodes.

2. Relevance of the catheter hub as a portal for microorganisms causing catheter-related bloodstream infections. M B Salzman, L G Rubin. Nutrition. 1997 Apr;13(4 Suppl):15S-17S. doi: 10.1016/s0899-9007(97)00217-7. PMID: 9178305

3. Use of disinfectants to reduce microbial contamination of hubs of vascular catheters. Salzman MB, Isenberg HD, Rubin LG. J Clin Microbiol. 1993. Mar;31(3):475-9. PMID: 8458938

4.Microbial contamination of anesthetic syringes in relation to different handling habits. Florian Heid, Carolin Bender, Hendrik Gervais, Joachim Schmeck, Wolfgang Kohnen, Rüdiger Noppens. Am J Infect Control. 2016 Mar 1;44(3):e15-7. Epub 2015 Nov 7. PMID: 26559736

5. Microbial contamination of syringes during preparation: the direct influence of environmental cleanliness and risk manipulations on end-product quality. Stucki C, et al. Am J Health Syst Pharm. 2009. PMID: 19890087

6. Microbial stability of syringes of anesthetic drugs prepared in the operating room. Scott Segal, Antonius Gunawan, Douglas H McLaughlin, Elizabeth Palavecino. J Clin Anesth. 2019 Aug;55:20-23. PMID: 30586662

7. Anaesthetists and syringe hygiene: getting to the pointy end - a summary of recommendations. Lloyd E Kwanten. Br J Anaesth. 2019 Oct;123(4):e475-e479. PMID: 31248642

IV Port Asepsis Compliance

1. Infection prevention in the operating room anesthesia work area. Munoz-Price LS, Bowdle A, Johnston BL, Bearman G, Camins BC, Dellinger EP, Geisz-Everson MA, Holzmann-Pazgal G, Murthy R, Pegues D, Prielipp RC, Rubin ZA, Schaffzin J, Yokoe D, Birnbach DJ. Infect Control Hosp Epidemiol. 2019 Jan;40(1):1-17. doi: 10.1017/ice.2018.303. Epub 2018 Dec 11. PMID: 30526699

2. Disinfection of Needleless Connector Hubs: Clinical Evidence Systematic Review. Moureau NL, Flynn J.Nurs Res Pract. 2015;2015:796762. Epub 2015 May 14. Review. PMID: 26075093

Tubing Misconnections and Wrong-Route Infusion or Injection Drug Errors

1. Viscusi ER, Hugo V, Hoerauf K, Southwick FS. Neuraxial and peripheral misconnection events leading to wrong-route medication errors: a comprehensive literature review. Reg Anesth Pain Med. Feb 2021;46(2):176-181. doi:10.1136/rapm-2020-101836

2. Ethington S, Volpe A, Guenter P, Simmons D. The lingering safety menace: A 10-year review of enteral misconnection adverse events and narrative review. Nutr Clin Pract. Jul 18 2024;doi:10.1002/ncp.11191

3. Guenter PaC, M. Misconnections and the Emergence of Enteral Nutrition Connectors for Patient Safety. Infusion. 2020;(September / October):26-29.

4. Feito Sancho J. NRFit connectors in regional anaesthesia: avoiding medication errors. Rev Esp Anestesiol Reanim (Engl Ed). Aug-Sep 2024;71(7):538-544. doi:10.1016/j.redare.2024.04.012

5. Amiot J, Bruge Ansel MH, Bruyas M, et al. Strategy to secure the neuraxial route in anaesthesia: Risk mapping and feedback from the application of the ISO 80369-6 standard NRFit(R) connectors. Ann Pharm Fr. Jun 2024;82(4):706-717. doi:10.1016/j.pharma.2024.02.015

6. Vacheron CH, Piriou V, Untereiner O, et al. [NRFit: A new standard to prevent wrong-route medication errors]. Ann Pharm Fr. Jan 2023;81(1):30-39. NRFit : une nouvelle norme de connexion pour prevenir les erreurs medicamenteuses concernant les voies d'administration. doi:10.1016/j.pharma.2022.03.002

7. Cannons K, Shaw I. Changing practice for neuraxial applications using NRFit small-bore connectors to improve patient safety. Br J Nurs. Feb 25 2021;30(4):S22-S27. doi:10.12968/bjon.2021.30.4.S22

8. B. Braun Medical Announces First U. S. Conversion to NRFit® Connectors. July 24, 2024 Press release located at bbraunusa website; about us; media; company news; 2024. Accessed September 12, 2024.