

# Quantifying Contrast Medium Usage and Disposal in Neurointerventional Procedures

Johannes Pfaff

[j.pfaff@salk.at](mailto:j.pfaff@salk.at)

University Hospital Salzburg <https://orcid.org/0000-0003-0672-5718>

Ingrid Liedtke

University Hospital Salzburg <https://orcid.org/0009-0002-6079-3578>

Leonard Mondre

University Hospital Salzburg <https://orcid.org/0009-0007-6820-130X>

Georg Mosleitner

University Hospital Salzburg <https://orcid.org/0009-0004-3872-276X>

Ramona Schmidt

University Hospital Salzburg <https://orcid.org/0009-0004-9782-1178>

Nicole Cappelari

University Hospital Salzburg <https://orcid.org/0009-0004-5187-2594>

Markus Schober

University Hospital Salzburg <https://orcid.org/0009-0001-1654-5908>

---

## Research Article

**Keywords:** Waste Management (<http://id.nlm.nih.gov/mesh/D018505>), Endovascular Procedures (<http://id.nlm.nih.gov/mesh/D057510>), Iodixanol (<http://id.nlm.nih.gov/mesh/C044834>), Contrast Media (<http://id.nlm.nih.gov/mesh/D003287>), Waste Disposal, Fluid (<http://id.nlm.nih.gov/mesh/D014865>)

**Posted Date:** July 28th, 2026

**DOI:** <https://doi.org/10.21203/rs.3.rs-10495289/v1>

**License:** © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

**Additional Declarations:** The authors declare potential competing interests as follows: JARP: Grants: Vesalio. Honoraria/Speaker fees: Boehringer Ingelheim AG & Co. KG, Eli Lilly GmbH, Medtronic, Siemens Healthcare Diagnostics GmbH. Travel: Cerenovus (Johnson & Johnson Medical Products GmbH), Vesalio. All other authors declare no conflict of interest.

---

# Abstract

## Background:

Data on contrast medium usage and disposal during neurointerventional procedures are limited.

## Purpose:

This study quantifies the volume and proportion of provided and disposed contrast medium for neurointerventional procedures.

## Material and Methods:

In this prospective observational study conducted at a tertiary care hospital, contrast medium usage and disposal were measured across neurointerventional procedures over a 90-day period. Data included contrast used for manual DSA runs and 3D rotational angiographies with a power injector, as well as unused contrast medium disposal.

## Results:

A total of 100 neurointerventional procedures were performed from April 1st to June 30th, 2025. On average,  $166.5 \pm 64.4$  mL of contrast medium was provided per procedure, with  $58.6 \pm 37$  mL (35.2%) disposed. The lowest mean provided volume was observed in endovascular treatment of intracranial vasospasm ( $116.7 \pm 40.8$  mL), and the lowest mean used volume in carotid artery stenting ( $75 \pm 21.9$  mL). Embolization procedures with liquid embolics showed the lowest disposed volume and rate ( $34.4 \pm 32.7$  mL, 27%), whereas embolization procedures with coils, flow-diverters, or intraaneurysmal flow-disruptors had the highest provided volume ( $234.2 \pm 60.2$  mL) and disposal rate and volume (38.4%,  $90 \pm 27.6$  mL). Disposal rates ranged from a minimum of 23.3% for manual DSA runs to a maximum of 71.4% for 3D rotational angiographies with a power injector.

## Conclusion:

Neurointerventional procedures require considerable amounts of contrast medium, with disposal rates and volumes varying notably based on procedural complexity and the method of administration (manual vs. power injector).

## Summary Statement

The usage and disposal of contrast medium in neurointerventional procedures, including diagnostic angiography and endovascular treatments, exhibit considerable variation depending on the procedural complexity and the method of administration.

## What is already known on this topic

Healthcare, including neurointerventional procedures, contributes significantly to environmental waste, and contrast media are partially disposed of after procedures. While cardiology studies have reported contrast medium consumption, there is a lack of quantitative data on contrast medium usage, disposal, and waste specifically in neurointerventional procedures.

## Key Results - What this study adds

- On average, 35.2% of contrast medium provided for neurointerventional procedures is disposed unused, with disposal rates varying by procedure type and administration method.
- Manual DSA runs result in 23.3% to 35.7% disposal, whereas 3D rotational angiographies using a power injector show much higher disposal rates of 54.5% to 71.4%.
- Across 100 procedures, a total of 5.9 liters of contrast medium was disposed, translating to an estimated annual disposal of 23.5 liters, suggesting procedural inefficiency.

## How this study might affect research, practice or policy

These findings emphasize the need for standardized protocols and waste-reduction strategies in neurointerventional procedures. They support research into optimized contrast medium administration, encourage the sharing of best practice models for efficient contrast medium use, and promote sustainable disposal practices.

## Introduction

The contemporary healthcare sector, while fundamentally dedicated to the preservation and enhancement of human well-being, inadvertently bears a substantial environmental footprint. (1–4) Within this broader context, specialized medical procedures, such as neurointerventional procedures, are not exempt from these environmental challenges. These complex procedures frequently generate considerable volumes of solid waste, directly attributable to their supply chains and the demanding material requirements inherent in their execution. (5–7)

Despite the growing recognition of healthcare's environmental impact, a notable gap persists in the current academic literature concerning the precise quantification of contrast medium volumes specifically supplied for neurointerventional procedures, as well as the subsequent disposal practices associated with any unused contrast media. Given the increasing frequency of minimally invasive neurointerventions and the limited scope of current data, there remains a critical gap in our understanding of the true scale of contrast media usage and disposal during neurointerventional procedures.

This study aims to quantify the volume of provided, used, and unused (disposed) contrast medium in both diagnostic and therapeutic neurointerventions. Additionally, it seeks to assess the proportion of unused contrast medium generated during these procedures.

## Methods

### Study Design and Setting

This was a prospective observational study conducted in the neurointerventional angiosuite of a tertiary care hospital, University Hospital Salzburg, Salzburg, Austria, with a particular focus on contrast medium utilization patterns. The study aimed to measure and evaluate the usage and disposal of contrast medium during neurointerventional procedures. Data collection occurred continuously over a 90-day period from April 1st until June 30th 2025.

### Study Material

During the observation period, the total amount of contrast medium provided, the amount of contrast medium used and the amount of not used and consequently disposed contrast medium was recorded for each neurointerventional procedure.

#### Contrast medium provided

"Contrast Medium Provided" was defined as the overall volume of contrast medium that was made available and allocated for the respective neurointerventional procedure.

#### Contrast medium used

The term "contrast medium used" encompasses any medical use or application of the contrast medium within the context of the respective procedure. The majority of the contrast medium used was utilized for diagnostic series or 3D rotational angiographies. The volume of contrast medium used also includes minor quantities that were needed for line flushing, preparation and usage of devices such as PTA balloons, or possibly lost due to spillage. These small amounts of contrast medium are not reliably quantifiable in clinical routine cases, which is why they were not recorded separately. Therefore, the term "contrast medium used" does not equate to "contrast medium injected," and as such, does not describe the exact, but only approximates volumes of contrast agent administered to a patient.

## DSA runs

For each procedure, the standard initial volume of contrast medium provided was 100 mL of Iodixanol (Visipaque 270, GE Healthcare, USA) for DSA runs. Additional contrast medium, in vials containing either 50 mL or 100 mL of contrast medium, was provided at the discretion of the neurointerventionalist, based on clinical judgment and procedural requirements. For each contrast medium run, a 10 mL syringe was prepared, filled with a standardized volume of 6 mL of contrast medium mixed with 2 mL of isotonic saline solution (Fresenius Kabi isotonische Kochsalzlösung 0,9%, Fresenius Kabi Deutschland GmbH, Germany), drawn up air-bubble free and administered via the respective catheter. Contrast administration was performed by manual injection by the neurointerventionalist with an injection rate of approximately 4 to 5 mL/s.

#### 3D rotational angiographies

3D rotational angiographies were acquired using a power injector loaded with 100 mL of Iodixanol (Visipaque 320, GE Healthcare). Administration of contrast medium for 3D rotational angiographies followed a standardized protocol consisting of 21 mL, flow rate: 3 mL/second, without a bolus chaser, administered via the respective catheter. The start of contrast medium injection for 3D rotational angiographies was electronically synchronized to the imaging acquisition of our angiography system.

#### Contrast medium disposed

"Contrast Medium Disposed" was defined as the amount of contrast medium that, although theoretically still usable for this or another medical procedure, was disposed at the end of the procedure due to hospital hygiene guidelines, and thus no longer had any further medical use.

### Data Sources and Measurements

Data collection began when the staff started preparing for the procedure and ended after the patient had left the operating room, and all provided, used and disposed contrast medium volumes were recorded. No exclusion criteria were applied in the selection of procedures for observation. The collected data was recorded in a prospective database and subsequently analyzed with particular attention to contrast medium metrics. All measurements and their completeness checks regarding contrast medium were performed by the angiography staff immediately after completion of the respective neurointerventional procedure. To reduce observer bias, all measurements related to contrast medium were conducted by the same trained angiography staff following a standardized protocol.

## Study Size

The sample size was defined by the number of neurointerventional procedures performed during the 90-day observation period. No sample size calculation was performed, as the study aimed to descriptively analyze the full cohort.

## Quantitative Variables

Quantitative variables included volumes in mL for contrast medium.

## Statistical Methods

Descriptive statistics were used to summarize the data. No inferential statistical analyses were conducted, as the focus was on descriptive characterization. Statistics were performed using IBM SPSS Statistics (Version: 29.0.2.0 (20)).

## Ethical considerations

No patient-related data was collected. Formal ethics approval was not required.

# Results

## Procedure Characteristics

During the observation period, a total of 100 neurointerventional procedures were performed, and data from all procedures were included in this analysis. The most frequently performed procedures were diagnostic cerebral angiographies ( $n = 28$ ) and mechanical thrombectomies ( $n = 25$ ), followed by carotid artery stenting ( $n = 13$ ), embolization procedures using coils, flow-diverters or intraaneurysmal flow-disruptors, e.g. for treating aneurysms or carotid-cavernous fistulas ( $n = 19$ ), and embolizations using liquid embolic agents—such as for arteriovenous malformations, arteriovenous fistulas, or embolization of the middle meningeal artery ( $n = 9$ ). In addition, intra-arterial treatment of vasospasm following acute subarachnoid hemorrhage was performed in 6 cases.

## Contrast medium provided, used and disposed

Overall, a combined average of  $166.5 \pm 64.4$  mL (range: 100–350 mL) of contrast medium was provided per procedure to perform digital subtraction angiography runs and rotational angiographies for 3D imaging as needed. Of this, a mean of  $107.9 \pm 51.6$  mL contrast media was used, respectively a mean of  $58.6 \pm 37$  mL or 35.2% was disposed unused (Table 1). The highest mean volumes of contrast medium provided were observed in diagnostic angiographies and embolization procedures using coils, flow-diverters or intraaneurysmal flow-disruptors, averaging  $194.6 \pm 58.3$  mL and  $234.2 \pm 60.2$  mL, respectively. These two types of procedures also had the highest average amounts of disposed contrast medium ( $74.5 \pm 43.9$  mL and  $90 \pm 27.6$  mL, respectively); additionally, in terms of the percentage of disposed contrast medium, diagnostic angiography (38.3%) and embolization procedures using coils, flow-diverters or intraaneurysmal flow-disruptors (38.4%) had the highest overall contrast medium disposal rates. Across all procedures observed in our study, a total of 5.9 liters of unused contrast medium was disposed. The estimated annual amount of contrast medium that we dispose unused would be approximately 23.5 liters.

Table 1

shows the amount of provided contrast medium and the amount of used and disposed contrast medium for all procedures by procedure type.

|                                                                                                                                                                                                                                                                                                                                                                                                                            | Overall<br>Number<br>of<br>Patients | Overall<br>provided<br>contrast<br>medium<br>(mL) | Overall<br>used<br>contrast<br>medium<br>(mL) | Overall<br>disposed<br>contrast<br>medium<br>(mL) | Number<br>of<br>Patients<br>Visi-<br>paque<br>270 mg<br>provided | Visi-<br>paque<br>270 mg<br>provided<br>(mL) | Visi-<br>paque<br>270 mg<br>used<br>(mL) | Visi-<br>paque<br>270 mg<br>disposed<br>(mL) | Number<br>of<br>Patients<br>Visi-<br>paque<br>320 mg<br>provided | Visi-<br>paque<br>320 mg<br>provided<br>(mL) | Visi-<br>paque<br>320 mg<br>used<br>(mL) | Visi-<br>paque<br>320 mg<br>disposed<br>(mL) |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|---------------------------------------------------|-----------------------------------------------|---------------------------------------------------|------------------------------------------------------------------|----------------------------------------------|------------------------------------------|----------------------------------------------|------------------------------------------------------------------|----------------------------------------------|------------------------------------------|----------------------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                            | n                                   | Mean<br>(SD)                                      | Mean<br>(SD)                                  | Mean<br>(SD)                                      | n                                                                | Mean<br>(SD)                                 | Mean<br>(SD)                             | Mean<br>(SD)                                 | n                                                                | Mean<br>(SD)                                 | Mean<br>(SD)                             | Mean<br>(SD)                                 |
| All<br>Procedures                                                                                                                                                                                                                                                                                                                                                                                                          | 100                                 | 166.5<br>(64.4)                                   | 107.9<br>(51.6)                               | 58.6<br>(37)                                      | 100                                                              | 132.5<br>(48.9)                              | 94.8<br>(45.7)                           | 37.7<br>(21.4)                               | 34                                                               | 100<br>(0)                                   | 38.4<br>(21.8)                           | 61.6<br>(21.8)                               |
| DSA                                                                                                                                                                                                                                                                                                                                                                                                                        | 28                                  | 194.6<br>(58.3)                                   | 120.1<br>(62.5)                               | 74.5<br>(43.9)                                    | 28                                                               | 126.8<br>(55.2)                              | 89.3<br>(55.4)                           | 37.5<br>(24.4)                               | 19                                                               | 100<br>(0)                                   | 45.5<br>(23.7)                           | 54.5<br>(23.7)                               |
| EST                                                                                                                                                                                                                                                                                                                                                                                                                        | 25                                  | 134<br>(31.4)                                     | 95.8<br>(31.7)                                | 38.2<br>(19.4)                                    | 25                                                               | 134<br>(31.4)                                | 95.8<br>(31.7)                           | 38.2<br>(19.4)                               | 0                                                                | n.a.                                         | n.a.                                     | n.a.                                         |
| Embolization<br>(Coils, Flow-<br>Diverters,<br>Flow-<br>Disruptors)                                                                                                                                                                                                                                                                                                                                                        | 19                                  | 234.2<br>(60.2)                                   | 144.1<br>(56)                                 | 90<br>(27.6)                                      | 19                                                               | 160.5<br>(65.8)                              | 123.1<br>(53.9)                          | 37.4<br>(22.4)                               | 14                                                               | 100<br>(0)                                   | 28.6<br>(15.9)                           | 71.4<br>(15.9)                               |
| CAS                                                                                                                                                                                                                                                                                                                                                                                                                        | 13                                  | 119.2<br>(32.5)                                   | 75<br>(21.9)                                  | 44.2<br>(20.5)                                    | 13                                                               | 111.5<br>(21.9)                              | 71.8<br>(20.7)                           | 39.8<br>(12.6)                               | 1                                                                | 100<br>(n.a.)                                | 42<br>(n.a.)                             | 58<br>(n.a.)                                 |
| Embolization<br>(Liquid<br>Embolics)                                                                                                                                                                                                                                                                                                                                                                                       | 9                                   | 127.8<br>(44.1)                                   | 93.3<br>(36)                                  | 34.4<br>(32.7)                                    | 9                                                                | 127.8<br>(44.1)                              | 93.3<br>(36)                             | 34.4<br>(32.7)                               | 0                                                                | n.a.                                         | n.a.                                     | n.a.                                         |
| Vasospasm                                                                                                                                                                                                                                                                                                                                                                                                                  | 6                                   | 116.7<br>(40.8)                                   | 78.8<br>(39.1)                                | 37.8<br>(12.1)                                    | 6                                                                | 116.7<br>(40.8)                              | 78.8<br>(39.1)                           | 37.8<br>(12.1)                               | 0                                                                | n.a.                                         | n.a.                                     | n.a.                                         |
| Note: Overall contrast medium includes the combined amounts of contrast medium used for manual preparation and hand-injections (i.e., Visipaque 270 mg) as well as the contrast medium used exclusively for injections during 3D rotational angiography performed with a power injector (i.e., Visipaque 320 mg). DSA = digital subtraction angiography, CAS = carotid artery stenting, EST= endovascular stroke treatment |                                     |                                                   |                                               |                                                   |                                                                  |                                              |                                          |                                              |                                                                  |                                              |                                          |                                              |

While the above data represent the combined average usage of provided, used, and disposed contrast medium, analyzing contrast medium usage for hand-injected contrast runs versus 3D rotational angiography using a power injector reveals distinct differences. The mean average volumes of provided, used, and disposed contrast medium for contrast runs in 100 cases were  $132.5 \pm 48.9$  mL,  $94.8 \pm 45.7$  mL, and  $37.7 \pm 21.4$  mL, respectively. This corresponds to a disposed contrast medium percentage of 28.5% of the provided contrast agent for all contrast runs.

Carotid artery stenting procedures had the highest disposal rate of manually prepared contrast medium, with an average of  $39.8 \pm 12.6$  mL (35.7%) disposed per procedure. However, carotid artery stenting was, after the treatment of vasospasms ( $116.7 \pm 40.8$  mL), the procedure for which the second least amount of contrast medium was provided for manual use ( $116.7 \pm 40.8$  mL). The lowest percentage of disposed contrast medium was found in endovascular treatments utilizing coils, flow-diverters, or flow-disruptors, with a disposal rate of 23.3%. In these procedures, however, the greatest volume of contrast medium was provided for hand-injected contrast runs, with a mean of  $160.5 \pm 65.8$  mL.

In contrast, for thirty-four cases involving 3D rotational angiography, the respective volumes of provided, used, and disposed contrast medium were  $100 \pm 0$  mL,  $38.4 \pm 21.8$  mL, and  $61.6 \pm 21.8$  mL, with a very high disposal rate of 61.6%. Details on the procedure specific volumes of provided, used and disposed contrast medium can be found in the supplemental material.

## Discussion

This study investigates the quantities and efficiency of contrast medium utilization during neurointerventional procedures, offering a comprehensive analysis across 100 cases, ranging from diagnostic angiography to more specialized procedures such as aneurysm embolization and carotid artery stenting. Our findings reveal that on average 35.2% of provided contrast medium is consistently disposed. However, there are distinct differences in contrast medium disposal based on the method of administration and procedure complexity. The proportion of disposed contrast medium for manual preparation and DSA runs using hand injections ranges from 23.3% to 35.7%, while for 3D rotational angiographies using a power injector, we observed disposal rates between 54.5% and 71.4%. Additionally, the overall disposal rate of contrast medium varies from 27% to 38.4% depending on the procedure complexity.

At present, there are no national or international guidelines guiding the choice of contrast medium injection technique in diagnostic cerebral angiography. (8) Nevertheless, our standard method of administering contrast medium is consistent with practices reported in the literature. (9–11). It is notable that while the current literature provides information concerning suggested flow rates for cerebral angiography and the impact of contrast medium temperature or saline mixtures on these rates (11, 12), there is a lack of data on average contrast medium consumption or its disposal in neurointerventional procedures. Both, hand injections for contrast runs and 3D rotational angiographies using a power injector, often leave unused contrast medium in the syringe or injector,

contributing to procedural waste and healthcare costs. Consequently, our data should be viewed as an initial effort to benchmark contrast medium usage and disposal in neurointerventional procedures.

For endovascular cardiological procedures, the use of contrast medium injectors for all diagnostic series has led to a notable reduction in both the total volume of contrast medium injected into patients and the amount of contrast medium wasted. (13) However, even in diagnostic coronary angiography it is not consistently evident that the use of contrast injectors always reduces the need for contrast medium (14), and comparable data for neurointerventional procedures are lacking.

Nevertheless, unused and disposed contrast medium represents a source of economic inefficiency with the potential for environmental harm. Contrast medium leakage into wastewater systems is an ongoing concern (15, 16) with trace amounts of contrast mediums found in drinking water sources (17), highlighting the urgency for improved disposal practices. The environmental impact of iodine underscores the importance of finding sustainable disposal methods, such as recycling iodine from contrast medium or waste water to create a circular economy for this essential resource. (18, 19) It is crucial that contrast medium is not discharged into wastewater or groundwater. (20) In our hospital, we have adopted a policy of separate collection and proper disposal of contrast medium, aiming to ensure that iodine can be recovered and reused. Disposal of medications or pharmaceutical chemicals, including contrast media, is stated to cost €242.00 or approximately \$285.00 per ton excluding tax by the local waste disposal provider in 2026. However, since we do not reach this quantity, disposal costs for smaller volumes of unused contrast medium are higher.

Despite our findings, there are several limitations in our study. First, this is a single-center study, and the findings may not fully reflect practices in other healthcare settings. Other approaches to contrast medium administration, e.g. a higher standard volume of contrast medium per DSA run or per 3D angiography, would of course also result in higher overall consumption, and possibly to different levels of utilization efficiency and contrast medium waste. Second, variations in treatment approaches, such as the type of aneurysm therapy used, e.g. coil-embolization vs. placement of a flow-diverter or flow-disruptor, could lead to differences in procedure length and therefore contrast medium consumption and were not accounted for in this study. Finally, our study does not explore the potential benefits of contrast medium reduction interventions, such as the adoption of contrast injectors for all diagnostic series, which might change contrast medium usage and disposal patterns.

Further studies could explore how different administration strategies impact both contrast medium usage and waste generation and economical and ecological outcomes. Additionally, while our study provides a snapshot of contrast medium consumption during neurointerventional procedures, a longitudinal study incorporating waste management practices and evaluating the effectiveness of contrast medium waste-reduction interventions would be beneficial.

## Conclusion

Neurointerventional procedures involve substantial use of contrast medium and the disposal of unused portions, with considerable variability depending on procedural complexity and injection method. This study underscores the need for more sustainable practices to optimize contrast medium usage, particularly given the differences in disposal rates across procedures.

## Abbreviations

AVF  
arterio-venous fistula  
AVM  
arterio-venous malformation  
CAS  
carotid artery stenting  
DSA  
digital subtraction angiography  
MMA  
middle meningeal artery  
MT  
mechanical thrombectomy

## Declarations

## Conflict of Interests:

JARP: Grants: Vesalio. Honoraria/Speaker fees: Boehringer Ingelheim AG & Co. KG, Eli Lilly GmbH, Medtronic, Siemens Healthcare Diagnostics GmbH. Travel: Cerenovus (Johnson & Johnson Medical Products GmbH), Vesalio. All other authors declare no conflict of interest.

## Author contributions:

Johannes Alex Rolf Pfaff: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing; Ingrid Liedtke: Data curation, Formal analysis, Project administration, Writing -

original draft, Writing - review & editing; Leonard Mondre: Data curation, Investigation, Writing -review & editing; Georg Mosleitner: Data curation, Investigation, Writing - review & editing; Nicole Cappelari: Data curation, Investigation, Writing - review & editing; and Ramona Gschwandtner: Data curation, Investigation, Writing - review & editing; Markus Schober: Data curation, Investigation, Project administration, Supervision, Writing -review & editing.

## References

1. Wyssusek KH, Keys MT, van Zundert AAJ (2019) Operating room greening initiatives - the old, the new, and the way forward: A narrative review. *Waste Manag Res* 37(1):3–19
2. Tee NCH, Yeo JA, Choolani M, Poh KK, Ang TL (2024) Healthcare in the era of climate change and the need for environmental sustainability. *Singap Med J* 65(4):204–210
3. Or Z, Seppänen AV (2024) The role of the health sector in tackling climate change: A narrative review. *Health Policy* 143:105053
4. Rizan C, Bhutta MF, Reed M, Lillywhite R (2021) The carbon footprint of waste streams in a UK hospital. *J Clean Prod* 286:125446
5. Pfaff JAR, Schober M, Seethaler C, Oellerer A, Scheiber B, Liedtke IL (2025) Unpacking the problem-the hidden waste in neurointerventional procedures: quantifying packaging waste in neurointerventional supply chains. *J neurointerventional Surg*
6. Shum PL, Kok HK, Maingard J, Schembri M, Bañez RMF, Van Damme V et al (2020) Environmental sustainability in neurointerventional procedures: a waste audit. *J neurointerventional Surg* 12(11):1053–1057
7. Pfaff JAR, Liedtke IL, Eichinger S, Faistauer E, Kinz T, Schober M (2026) Green Neurointerventions: Quantifying Waste Generation and Assessing Ecological and Economic Implications of Current Practices. *Radiology* 318(2):e252784
8. Dehlinger N, Dillenseger JP, Pop R, Hasiu A, Bonnard L, Leonard-Lorant I (2025) Towards standardised contrast injection protocols in diagnostic cerebral angiography for unruptured aneurysm evaluation: Addressing the current variability and technical challenges. *Radiography (Lond)*. :103254
9. Ahn SH, Prince EA, Dubel GJ (2013) Basic neuroangiography: review of technique and perioperative patient care. *Semin Intervent Radiol* 30(3):225–233
10. Kwon B, Lee KB, Yoon JT, Choi JH, Lee DH, Song Y (2022) Safety and Effectiveness of the Novel Catheter 3.0 System for Diagnostic Cerebral Angiography: A Pilot Study. *Neurointervention* 17(3):143–151
11. Yousem DM, Trinh BC (2001) Injection rates for neuroangiography: results of a survey. *AJNR Am J Neuroradiol* 22(10):1838–1840
12. Bayraktar EA, Li J, Cortese J, Bilgin C, Ueki Y, Kadirvel R et al (2024) Optimizing the hemodynamics of hand injections in neuroangiography. *Interventional neuroradiology: J peritherapeutic Neuroradiol Surg procedures Relat neurosciences* 30(6):833–838
13. Anne G, Gruberg L, Huber A, Nikolsky E, Grenadier E, Boulus M et al (2004) Traditional versus automated injection contrast system in diagnostic and percutaneous coronary interventional procedures: comparison of the contrast volume delivered. *J Invasive Cardiol* 16(7):360–362
14. Hwang JR, D'Alfonso S, Kostuk WJ, Diamantouros P, Teefy P, Jablonsky G, Lavi S (2013) Contrast volume use in manual vs automated contrast injection systems for diagnostic coronary angiography and percutaneous coronary interventions. *Can J Cardiol* 29(3):372–376
15. Pichler V, Martinho RP, Temming L, Segers T, Wurm FR, Koshkina O (2025) The Environmental Impact of Medical Imaging Agents and the Roadmap to Sustainable Medical Imaging. *Adv Sci (Weinh)* 12(9):e2404411
16. Yan H, Zhang T, Yang Y, Li J, Liu Y, Qu D et al (2024) Occurrence of iodinated contrast media (ICM) in water environments and their control strategies with a particular focus on iodinated by-products formation: A comprehensive review. *J Environ Manage* 351:119931
17. Cheng X, Xia Y, Ji Q, Ji Q, Li H, Guo J et al (2023) Occurrence and risk of iodinated X-ray contrast media in source and tap water from Jiangsu province, China. *J Hazard Mater*. ;444(Pt A):130399.
18. Beer M, Schuler J, Kraus E, Zhou S, Stanzel S, Lorenz S et al (2023) Discharge of iodine-containing contrast media into the environment - problem analysis and implementation of measures to reduce discharge by means of separation toilets - experience from a pilot project. *Rofo* 195(12):1122–1127
19. Dekker HM, Stroomberg GJ, Prokop M (2022) Tackling the increasing contamination of the water supply by iodinated contrast media. *Insights Imaging* 13(1):30
20. Rusandu A, Bustadmo L, Gravvold H, Anvik MS, Skilleås Olsen K, Hanger N (2024) Iodinated contrast media waste management in hospitals in central Norway. *Radiography (Lond)* 30(5):1272–1276

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Pfaffcontrastmediasupplementalmaterial20260724.docx](#)