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The rediscovered unknown “small Ruijsch collection” of dry and wet anatomical specimens

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Abstract. Peter the Great (1672–1725) – the Russian emperor travelled through Europe during the so-called “Great Embassies” to acquire knowledge in the field of science and industrial production. In Amsterdam (Netherlands), he received as a gift from Frederik Ruijsch samples of dried and wet anatomical specimens, consisting of objects of both natural history and human origin, and currently called the “small collection”. The anatomical part of the collection consisted of 11 dry and 13 wet specimens, parts of the human body. The authors rediscovered this collection in 2016 among the exhibits of the fundamental museum of the department of normal anatomy of the Military Medical Academy (St. Petersburg, Russia). In the article we describe the current state of this historical collection, which played an important role in the acquisition of a more extensive collection by Peter the Great from Ruysch for the Kunstkamera (Museum of Anthropology and Ethnography of Peter the Great in St. Petersburg). The Kunstkamera collection is open to the general public, and as a result is well known through publications in literature. On the contrary, the so-called “small collection” was, from the moment of its arrival in Russia in 1698, in the personal possession of Peter the Great. He later divided his small collection for educational purposes between the Aptekerskii Prikaz and the medical school of Nicolaas Bidloo. Around 1800, both parts of the small collection were reunited and transferred to the Medical-Surgical Academy. Today, this collection still serves educational purposes, but is not widely available to the general public. As a result, it remains virtually unknown.

Keywords: anatomy; history; medicine; Peter the Great; Ruijsch; Netherlands; Russia (pre-1917)

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HISTORY OF MORPHOLOGY

Original article

Неизвестная «малая коллекция Рюйша» сухих и влажных анатомических препаратов

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Аннотация. Петр Великий (1672–1725) – российский император путешествовал по Европе во время так называемых «Великих посольств» с целью приобретения знаний в области науки и промышленного производства. В Амстердаме (Нидерланды) он получил в дар от Фредерика Рюйша образцы высушенных и влажных анатомических препаратов, состоящих из предметов как естественно-исторического, так и человеческого происхождения, и в настоящее время именуемых «малой коллекцией». Анатомическая часть коллекции состояла из 11 сухих и 13 влажных препаратов, частей тела человека. Она была исследована авторами в 2016 году среди экспонатов фундаментального музея кафедры нормальной анатомии Военно-медицинской академии (Санкт-Петербург, Россия). В статье мы описываем современное состояние этой исторической коллекции, которая сыграла важную роль в приобретении Петром Великим у Рюйша более обширной коллекции для Кунсткамеры (Музей антропологии и этнографии Петра Великого в Санкт-Петербурге). Коллекция Кунсткамеры открыта для посещения широкой публикой, и в результате хорошо известна по публикациям в литературе. Напротив, так называемая «малая коллекция» находилась с момента своего прибытия в Россию в 1698 г. в личном владении Петра Великого. Позже он разделил

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свою небольшую коллекцию в образовательных целях между Аптекарским приказом и медицинской школой Николааса Бидлоо. Около 1800 года обе части малой коллекции были воссоединены и переданы в Медико-хирургическую академию. Сегодня данная коллекция, по-прежнему, служит образовательным целям, но мало доступна для широкой публики. В связи с этим она остается практически неизвестной.

Ключевые слова: анатомия; история; медицина; Петр Великий; Рюйш; Нидерланды; Россия (до 1917 г.)

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Introduction

Peter the Great, Emperor of Russia (1672–1725), travelled during the so-called Great Embassies to Europe to acquire scientific and industrial knowledge that he could apply in Russia for the further development of his country. On his first Great Embassy (1697–1698), he visited Amsterdam, Delft and Leiden in the Netherlands. In Leiden, he met with Govert Bidloo, Rector Magnificus of Leiden University at that time, to receive the Bylaws of the University that could inform him on how a university is organised [13, 14, 15]. Peter was interested in as Russia did not have a university at that time. In Amsterdam, he met Frederik Ruijsch (1638–1731), the famous anatomist and developer of an extensive collection of natural-historical and human-origin specimens [17, 24]. Peter showed great interest in the collection, frequently visited Ruijsch's museum, attended anatomy lectures in the anatomical theatre in Amsterdam, and participated in post-mortems [12, 20]. To express his gratitude to his teacher, Peter presented Ruijsch with a gift of sobole furs. Peter in return, obtained a small collection of specimens from Ruijsch, consisting of both natural-historical and human origin, dried and wet, fluid-conserved pieces (Fig. 1).

During the second Embassy in 1717, Peter acquired nearly the entire collection of Ruijsch, for which he paid the formidable sum of 30.000 Dutch Guilders. He shipped the collection to Saint Petersburg, intended to serve as educational material. It became a possession of the Academy of Science, and the collection is presently part of the collection of the Kunstkamera (Peter the Great Museum of Anthropology and Ethnography) in Saint Petersburg. Others extensively describe this collection and its importance [1, 2, 4].

Documentation of the origins and the journey of the dry and wet collection

Our article focuses on the gift from Ruijsch to Tsar Peter the Great, made in 1697–1698. It contains a set of 24 wet and dry specimens of mostly human origin, further referred to as the “Small Collection”. This collection was part of Peter’s private collection, kept initially in the Aptekarskii Prikaz in Moscow. In 1707 the Aptekarskii Prikaz was renamed to Aptekarskaya Kantselyarya. In the year 1707, the dry part of the collections was transferred from Aptekarskaya Kantselyarya in Moscow to the “Bidloo School” in Moscow. In 1712 the wet part of the collection was transferred with the Aptekarskaya Kantselyarya to Saint Petersburg, the new capital. The collection appeared in the inventory of 1762 of Meditsinskaya Kantselyariya [12]. In 1763, the wet specimens became part of the Cabinet of the Medistinskaya Kollegiya (former Aptekarskaya Kantselyarya, located next to the Hospital School of the General Second Landforce Hospital in Saint Petersburg (now the territory of the Military Medical Academy named SM Kirov). In 1798, Emperor Paul I closed the Imperial Medico-Surgical Academy (follow up of the Bidloo school) in Moscow. Its belongings, including the dry specimens of Ruijsch, were transferred to the Imperial Medico-Surgical Academy in St.Petersburg. This Academy in Saint Petersburg also received the wet collection from the Medistinskaya Kollegiya to create an anatomical cabinet [32, 33].

The historical journey of the small collection is extensively described earlier [12, 13, 14, 15, 35].

After establishing the Imperial Medico-Surgical Academy in 1798, the collection was first transferred to the Department of Physiological Anatomy of the Academy, prof. P.A. Zagorsky, head of the department, appreciated the Ruijsch collection very much. He corrected the anatomical names and recorded the specimens. He focused on accounting for the specimens in the inventory of the fundamental museum of the Department of Regular Anatomy of the Imperial Medico-Surgical Academy. Tables 1 and 2 are partly copies of Prof. Zagorsky's catalogue, supplemented with our findings while conserving the wet specimens (Table 1).

Other Academy professors who wrote about the collection are A.I. Tarenetsky [32], M.A. Tikotin [33], and V.V. Ginzburg [9, 10]. For some specimens, however, labels were not preserved. Therefore, to prove the identity as belonging to the “small collection”, we compared the available preparations of the museum with drawings in the catalogues of Ruijsch. Ruijsch published detailed descriptions of his home museum in Amsterdam through separate issues, "Catalogus Rariorum 1691 and Thesaurus Anatomicus

Fig. 1. Wet and dry preparations from the Frederik Ruysch collection. This small collection was privately owned by Tsar Peter the Great and is housed in the museum of the Anatomy Department of the Military Medical Academy, Saint Petersburg. Photographer R.I. Tamchenko. © Military Medical Academy, Saint Petersburg, *2020. Published with permission.*

Рис. 1. Влажные и сухие препараты из коллекции Фредерика Рюйша. Эта небольшая коллекция была частной собственностью царя Петра Великого и находится в музее кафедры анатомии Военно-медицинской академии, Санкт-Петербург. Фотограф Р.И. Тамченко. © Военно-медицинская академия, Санкт-Петербург , 2020. Опубликовано с разрешения.

Table 1 / Таблица 1

Overview of the dry human specimen of the small Ruysch collection
Обзор сухих человеческих препаратов из малой коллекции Рюйша

Nr. Catalogue Military Medical Academy	Tag number specimen	Description
233	253	Hand
230	250	Small skull
430	462	Dancing and grinning little boy
432	464	Small dancing monkey
	406	Specimen without arms and legs; Situs Inversus Totalis
76	88	Adult Aorta
57	67	Adult heart
60	70	Adult heart
61	71	Adult heart
64	74	Adult heart
65	75	Adult heart
68	78	Adult heart
	153	Adult heart
718	806	Adult heart. Situs Inversus.

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Primus – Magnus & Regius (Decimus)". In the military medical academy library, S.M. Kirov's work "Opera Thesauri Ruysch" is stored. These are intertwined catalogues presenting eleven issues, published between 1691 and 1731. Each catalogue has a number and a title, where is indicated which preparations it contains; then follows their enumeration and a brief description. At the end of each catalogue are written tables containing the most interesting anatomical specimens, with letter designations and a detailed explanation of the structure in the text. Table III of the fourth catalogue of Ruijsch, published in 1724, presents two images of an adult's heart with large vessels (Fig. 2).

Below it is written: "ad vitum sculp sit", i.e. "made of a living one". The inscription accompanies drawings of the heart: "Exhibet cor humanum cerarea materia rubra in totum repletum, et verus reptetus vasorum, vera cordis et auris kularum figura videri possint", i.e. "shows the human heart, filled with a red wax mass so that the true course of the vessels and the true forms of the heart and ears can be seen".

The small collection consisted of 11 dry and 13 fluid-preserved specimens. The dry specimens were all in excellent condition. The fluid-preserved specimens required further preservation, and the Department of Anatomy of the Leiden University Medical Center executed the preservation with the necessary expertise.

We describe the macroscopy of specimens, the findings during the conservation of the specimens and a detailed study of the composition of the coloured wax present in both the dry and wet preparations that Ruijsch used for conservation and cosmetic purposes.

The research aims to add to the historiography of anatomical collections used for medical education in the eighteenth century.

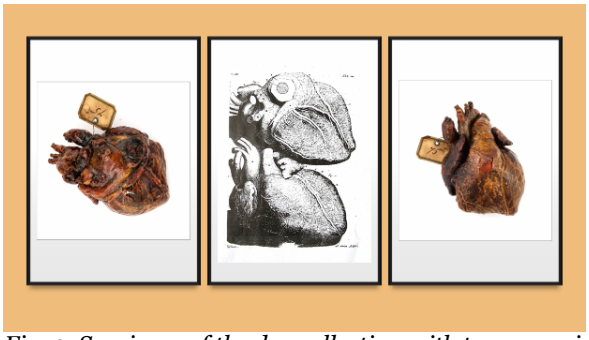

Fig. 2. Specimen of the dry collection with tag nr. 75 is a dried heart, Photographer R.I. Tamchenko. ©Military Medical Academy, Saint Petersburg, 2020. Published with permission. This specimen matches with Ruijsch's drawing in "Thesaurus Anatomicus Quartus cum figiris aeneis", Amstelodami, apud Janssonio-Waesbergios MDCCXXIV" (1720). In public domain.
Рис. 2. Сухой препарат сердца, метка №75. Фотограф Р.И. Тамченко. ©Военно-медицинская академия, 2020. Опубликовано с разрешения.
Этот образец соответствует рисунку Рюйша в "Thesaurus Anatomicus Quartus cum figiris aeneis", Амстердам, опубликовано Janssonio-Waesbergios MDCCXXIV, (1720). В общем доступе.

Methods

Conservation of the fluid-preserved preparations. Conservation of the specimens was performed at the Department of Anatomy of the Military Medical Academy in Saint Petersburg. Thirteen specimens were treated in a single week in October 2019. The methods of the fluid-preserved conservation were extensively discussed by Van Dam [35].

Analysis of the injected mass. Injected mass samples were taken for analysis from the dry and wet specimens. The samples taken were subjected to X-ray diffraction analysis using a Dron-3 diffractometer at a 30–40 kV voltage and a current strength of 20–30 mA. The decoding of the obtained results was carried out on a computer.

Results

The conservator (MT) of the anatomical department museum of the Military Medical Academy was confident that 8 of the 12 dry specimens and 9 of the 13 wet specimens belonged to the small Ruijsch collection, based on the documentation in the catalogues. The remaining 8 were attributed to Ruijsch, but the recordings were poorly documented. Supportive to this assumption that Ruijsch was the author of the specimens are the techniques used for the preparation, such as using iron wires as ligatures of the blood vessels to prevent loss of preservation fluids. The colouration used for the blood vessels with the deep red dye mercury sulphide is typical for the period. In some of the wet preparations, lace was used. This method is comparable to that used in some preparations in the Kunstkamera. The material is typical for the 17th century. We could not apply other techniques to determine the specimen's age. Almost all specimens were of human origin, based on the old catalogues belonging to the Military Medical Academy.

Among the preparations of Ruijsch's work are exotic animals and a monkey. By mistake, it has been assumed that the specimen with tag nr. 196 was the hand/foot of a young monkey. This assumption appears not to be true. After a careful and close look in the catalogues, it turned out to be an injected child's hand with an underdeveloped thumb and abnormal hair growth on the forearm. Additionally, a dry mummified skeleton of a tiny monkey has been identified as a Ruijsch specimen (tag nr. 464).

The small child's hand and all other specimens were foetal or neonatal. This is perhaps because Ruijsch, as professor of anatomy to the Guild of Surgeons of Amsterdam and as chief instructor of midwives, had insisted that all deceased neonates would be brought to him for further research [7, 19, 27, 28]. As such, the Ruijsch collection formed a milestone in knowledge about teratology and obstetrics [3, 16]. Teratology is also well represented in other historical collections, such as the collection of Leiden University.

Macroscopic description of dry and wet specimen

An overview of the dry specimen is given in Table 1. We will mark the number on the specimens (table 1, column 2). The overall quality of the dry specimens was excellent. Specimen tag nr. 464 is a skeleton of a monkey on natural ligaments with prepared muscles, limbs and arteries injected with a red mass. The veins and the right half of the heart are filled with an orange mass. A part of the skull is cut away on the right side. The front limb on the left is bent at the elbow joint and lifted; the lower jaw is slightly lowered. All this gives the skeleton of the monkey a characteristic dynamism to the preparations of Ruijsch. In a similar vein, specimen tag nr is exhibited. 462 a preparation of a small dancing boy who seems to be grinning. It is unsure if this was intentional or an artefact of the conservatory procedure. Specimen tag nr. 406 is a preparation with arms and legs removed, and the body's interior is shown. This preparation demonstrates a situs inversus totalis. The dry collection has a significant number of conserved hearts. Notable is specimen tag nr-806, which exhibits a situs inversus (Fig. 3).

An overview of the wet preparations and the conservation findings is given in Table 2. Undoubtedly, one of the most demonstrative preparations of Ruijsch is the alcohol preparation of a child's hand in its first years of life specimen tag nr. 198. The skin of the hand and the forearm are of natural pink colour. Soft tissues retain their bright pink colour on the horizontal cutting edge in the lower third of the shoulder. Individual muscle fibres, connective tissue layers, and

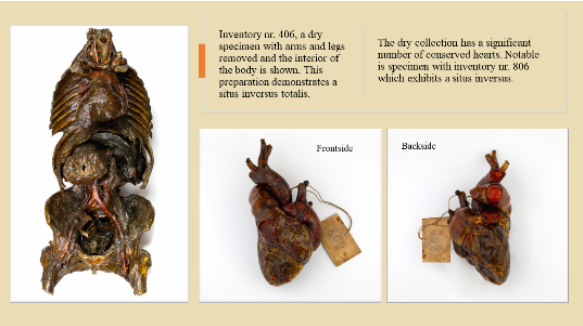

Fig. 3. Specimens from the dry collection with tag nr. 406 and 806 demonstrate a situs inversus totalis. Photographer R.I. Tamchenko. ©Military Medical Academy, Saint Petersburg, 2020. Published with permission.
Рис. 3. Сухой препарат situs inversus totalis с метками № 406 и 806. Фотограф Р.И. Тамченко. ©Военно-медицинская академия, Санкт-Петербург, 2020. Публикуется с разрешения.

shoulder vessels filled with a red-orange injection mass are well distinguished. The humerus on the cutting edge is brown. Inside the cerebral canal is a loose mass of reddish colour. The cutting edge and forearm area are decorated with a sleeve of thin white cambric and three rows of lace. The hand of the child is directed downwards. The fingers are naturally bent, and as with the most injected preparations of the fingers and the toes in the Ruijsch collection, the nails were removed, and the nail beds were pink.

The injected preparations of the hands and feet of the newborn have preserved their natural appearance. The skin of the foot (tag nr. 192) is juicy pink. The capillaries filled with injected mass are visible in the nail bed area. A white, thin veteran cuff surrounds the sliced section at the lower third part of the tibia. Through the tissue, the skin and muscles appear at the level of the cut.

Similarly, the hand of the newborn (tag nr. 202) looks natural. The small hand is turned down, the fingers of the child's hand are half-bent, and the wrinkles can be seen in the area of the wrist joint, characteristic of the hand of the newborn. Skin colour, position and formulation of the preparations all give them a living, natural appearance and give the impression of softness and swelling of the tissues of the paediatric hand and leg. However, these wholly injected anatomical preparations are very heavy and have a sculptural density.

Another group of alcohol preparations of Ruijsch are parts of the injected hands of a foetus without lace decorations. Their skin also retains a natural pink colour. Looking through a magnifying glass to the transverse cutting edge, all the tissues, the cartilage, muscle strings, interlayers of the connective tissue, blood vessels of muscles, and periosteum are discernible.

The preparation of the baby's head (tag nr. 255) in its first months of life is of great interest. The skin of the forehead, nose, cheeks, and chin are bright pink, and dark hair is well preserved on the head. The eyes and mouth are slightly ajar. The preparation is performed in the typical manner for Ruijsch. On top of a child's head, a part of the skull, the posterior cranial fossa, and the brain are removed. In the cutting edge, the injected soft tissues are visible. Inside the skull base, a part of the solid membrane of the brain with injected vessels is preserved. Similar exhibits can be admired in the Kunstkamera collection.

Conservation results of the fluid-preserved specimens

The conservation results of the fluid-preserved specimens of the 13 wet specimens are shown in Table 2 and based on the approved Condition Reports. These 13 reports are covered by the signed Agreement Conservation plan for “Small collection of 26 preparations from Fredrik Ruijsch". These condition reports and the agreement are owned by the Military Medical Academy in St. Petersburg and are not in open access or for the common public. All specimens presumable have been previously removed from their original containers. Both jars and lids had a shape that appeared at the earliest in the nineteenth century or possibly later and, therefore, were most probably not original. Labels (painted on the glass, paper labels either outside or inside) were present on glass containers. Over the years, the labels have been replaced and considered non-original.

They are attributed based upon the old handwritten catalogues to Ilya V. Buyalsky and Wenceslav L. Gruber, anatomy professors who were responsible for the collection and worked in the Imperial Medico-Surgical Academy (now the Military Medical Academy) in the first half of the 19th century.

Only a minority of lids completely sealed the jar, as only one did not leak during the leakage test. Five specimens were in excellent condition. Another five showed minor defects, such as arterial injection partly missing or fatty skin depositions. Nine jars contained ethanol as the preservation fluid, with a wide range of concentrations (43–87%). One jar contained formalin. The remaining three specimens with tags nr. 21, nr 255 and nr. 207 were in poor condition due to hardening of the skin and discolouration, and these three were preserved in turpentine.

It was hypothesised by the conservation team that the original preservation fluid was ethanol and that a later conservator had chosen erroneously to replace this with turpentine. The previous conservator possibly smelled an odour resembling turpentine after opening the jar. Turpentine was also used to inject the wax that Ruijsch used to make the wax thinner. So, while the specimen was initially probably placed in alcohol, after most of the alcohol had evaporated in due time, a more pungent turpentine smell arose from the injecting wax. When a specimen is

Table 2 / Таблица 2

Overview of the state of the wet human specimens of the small Ruysch collection prior to conservation
Обзор состояния влажных человеческих анатомических препаратов малой коллекции Рюйша до консервации

ID	Identification and tag number	Description	Quality of the specimen	Preservation fluid detected	Preservation fluid for further conservation
99	Tag nr. 105: painted on jar; O.A.* 2; one white-blue label at top of jar; one severely damaged label at bottom of the jar; latter possibly might be authentic Ruysch label.	Ear of a child	+/-	+/-; EtOH conc. 83%	EtOH conc. 70%
178	Tag nr. 196: white label with blue frame; number written up-side down with yellow crayon; in blue written Ruysch (in Russian); O.A. 13.	An injected child's hand with an underdeveloped thumb and abnormal development of the hairline on the forearm.	+	- -; formalin! (due to acidity and reactivity, might affect colour and overall quality of specimen); pH=4	EtOH conc. 70%, after steps of 30 and 50%
180	Tag nr. 198: on jar – O.A. 16; Two paper labels (partly damaged) one white-blue label at the top and the green label at the bottom.	Lower arm and hand of child; vascular injection with wax; decorated with lace	+	+/-; EtOH conc. 76%; slightly yellowed; red sediment on bottom jar	EtOH conc. 70%
181	Tag nr. 199: painted on jar: damaged white blue label at the bottom.	Foot of a neonatus; vascular injection with wax; decorated with lace, like the decorations of Ruysch preparations in the Kunstkamera.	+/-; efflorescence of calcium soaps on skin	-; EtOH conc. 85%(!); fluid loss	EtOH conc. 70%
183	Tag nr. 201: painted on jar; label preserved inside jar (on bottom).	Foot of a neonatus; vascular injection with wax; decorated with lace, like the decorations of Ruysch preparations in the Kunstkamera.	-; tissue has hardened and darkened (probably caused by replacing original fluid with turpentine)	-; turpentine (rectified?); severe yellowing	turpentine
184	Tag nr. 202: painted on jar; white label severely damaged – Monogram “B” on two laurels engraved in glass jar.	Hand of neonatus; vascular injection with red wax; decorated with lace	+	-; EtOH conc. 44%; fluid loss	EtOH conc. 70%
196	Tag nr. 214: painted on jar – 214 and label inside jar (on bottom); green label on jar; O.A. 34 – white-blue decorated label on jar	Foetal lower arm (antebrachium); vascular injection with red wax	+/-; arterial injected pigment missing at some areas of the skin	+/-; EtOH conc. 73%; fat globule on bottom of jar	EtOH conc. 70%

Table 2 (continuation) / Таблица 2 (продолжение)

199	Tag nr. 218: painted on jar – 218; ink on label inside jar (bottom); O.A. 38 - white-blue decorated label on jar; underneath green label	Foetal upper leg and hip; vascular injection with red wax	+/-; arterial injected pigment missing at some areas of the skin	+/-; EtOH conc. 73%; fat globules floating on preservation fluid; yellowing	EtOH conc. 70%
200	Tag nr. 219: ink on label inside jar (on bottom); O.A. 32	Foetal lower arm (antebrachium); vascular injection with red wax	+/-; arterial injected pigment missing at some areas of the skin	+/-; EtOH conc. 71%; slightly yellowed	EtOH conc. 70%
234	Tag nr. 255: painted on jar; O.A. 107	Neonatal head, vascular injection with coloured wax	+; intense red colour	-; EtOH conc. 87%(!); fluid loss; severe yellowing	EtOH conc. 70%

*OA = Museum of the descriptive anatomy.

ID: refers to the catalogue number of collections of the department of Normal Anatomy of the Military Medical Academy. *Tag Number on the jar:* refers to the tag number in the catalogue of the Military Medical Academy. *Quality of Specimen*: structural quality of the specimen. *Mounting*: the suspension of the specimen in the jar. *Preservation fluid*: quality as defined by level, pH, clarity, and concentration of the preservation fluid; evasions of the standard fluid ethanol are described. © *Authors produced this table, 2021.*

immersed in turpentine, which was before on alcohol, it will result in significant tissue shrinkage due to water extraction. Thus it would have resulted in considerable deformation of both the outer aspect and darkening of the tissues (Fig. 4 and 5). The damage it had caused was complete and at a point of stability. Since the fluid was unclear, it was replaced with turpentine. Switching back to ethanol was not an option as this would result in another shock effect, which would further harm the specimen. The tissue shrinkage due to the turpentine erxtraction of fluid cannot be reversed by changing it for another fluid.

Specimen with tag nr. 196, a small child's hand exhibited the typical smell of formaldehyde (Fig. 6).

Unbuffered formaldehyde has a nasty side effect: it acidifies enormously in due time when it converts to formic acid. The pH of the solution of our specimen was 4. Formaldehyde is a good fixative, but keeping specimens in unbuffered formaldehyde for hundreds of years is unwanted. Formaldehyde is an aqueous solution. One can change the fluid stepwise to ethanol. The specimen was placed in a container with an ethanol concentration of 30%, stepwise changing it to 50% and finally to 70% over several days.

The remaining nine specimens did not pose great conservation dilemmas as they were well maintained. The most significant problem of their current state was the low levels of the fluids due to leakage at the stopper and evaporation. The ethanol concentrations were in a wide range of 43-87%. The fluid was replaced with a solution of ethanol of 70%.

Analysis of the injected mass

Ruijsch's preparations were subjected to microscopic and X-ray examinations. The micropreparations stained by the Van Gieson method showed that most preparations' blood vessels are entirely injected. The capillaries and the venules of muscles are densely filled with an injected mass. The transverse striated striation of muscle strings is well preserved. A vascular pattern was revealed on the radiographs of a paediatric hand and a leg. The mass used by Ruijsch to fill the vessels was radiopaque.

We know that Ruijsch, neither to Tsar Peter the Great nor to Peter's employees, disclosed the mystery of "putting the dead bodies to rest." His method of embalming dead bodies, injecting vessel methods, or the injection mass formula is unknown, and there is also no precise information on the composition of the fixing fluid that Ruijsch used to preserve his specimens. To answer at least one of the questions posed, we examined pieces of tissue from wet specimens and fillers of large vessels from dry preparations. It was established that in all cases, the filling of the blood vessels is cinnabar, i.e., cinnabar HgS / mercury sulphide or red cinnabar, a natural mercury compound in combination with complex hydrocarbons - $C_{42}H_{22}O_4$ and $C_{15}H_{34}O_7$.

The spectral local-laser analysis of the same samples of the vascular fillers showed that the mixture contains more than 1% mercury, as well as impurities of more than 20 different substances: Ca 2.0–5.0%; Si, Al, Mg, Fe – 0.1–0.6%; Pb – 0.2–0.3%, as well as traces of Ni, Co, Cu, Ag,

Fig. 4. Specimens nr. 201 nr, 207 and 255 before restoration in October 2019. Photographer Ivan Gaivoronskii. ©Military Medical Academy, Saint Petersburg, 2017. Published with permission.
Рис. 4. Препараты № 201, № 207 и 255 до реставрации в октябре 2019 г. Фотограф Иван Гайворонский. ©Военно-медицинская академия, Санкт-Петербург, 2017. Публикуется с разрешения.

Fig. 5. The same specimens nr. 201, 207 and 255 in February 2022 after restoration in October 2019. We saw and concluded that even the structure and the colour of the specimen with number 207 have improved. Photographer R.I. Tamchenko. ©Military Medical Academy, Saint Petersburg, 2022. Published with permission.
Рис. 5. Те же препараты № 201, 207 и 255 в феврале 2022 г. после реставрации в октябре 2019 г. Мы увидели и пришли к выводу, что даже структура и цвет препарата с номером 207 улучшились. Фотограф Р.И. Тамченко. ©Военно-медицинская академия, Санкт-Петербург, 2022. Опубликовано с разрешения.

Sb, Bi, Sn and Zn. Perhaps these impurities are inherent in the natural compounds of mercury, or Ruijsch added them to the embalming.

The dried specimens have maintained their excellent condition over the ages. We presume that Ruijsch followed the techniques described by others, probably with adaptations. Like the wet specimens, the process before preservation must have involved dissection early after death, by which the blood from the larger vessel was removed. Then, an injection of the larger vessels with wax coloured with pigment or tallow micro-injections of the smallest blood vessels with a thinner solution with turpentine and a coloured pigment or even mercury [5, 6]. Ruijsch frequently followed this step with further dissection until he decided that the object would be preserved in that state. Then a process of desiccation would follow. Subsequently, the specimen would be placed in a preservative liquid, for example, water with added alum. In this case, it had to be previously emptied of blood by frequent washes in cold water. This procedure maintained the organ's volume and flexibility and allowed further work later on while maintaining its original appearance [36]. Ruijsch, who excelled at this technique, used a 'balsamic' liquor, whose composition remains unknown. The specimens were first submerged for 8–15 days in alcohol before soaking in a solution of 'spirit of vinegar' (acetic acid), to which was added 'corrosive sublimate' (mercuric chloride). The specimen was exposed to the air at a moderate temperature. When completely dry, the specimen was coated in a white varnish.

Ethyl alcohol preservation of biological specimens has a long history, starting with demonstrating its value by Robert Boyle's appearance before the Royal Society with a linnet (Linaria cannabina) and a little snake in some spirit of wine [31]. Frederik Ruijsch was among the first to use the "spirit of wine" to preserve biological tissues, most likely with 67 per cent alcohol by volume [11]. However, others suggest a lower concentration of 52% [26]. Ruijsch added other ingredients, such as black pepper or ethereal oils. Ruijsch is also well-known for using mercury sulphide-coloured resin injection into the blood vessels, using micro-injections of which he exhibited great skill. This led to specimens that showed great liveliness, approaching the complexion of the living organism, that appealed to the public, likewise, to Peter the Great. The samples were stored in glass jars. They were often closed with a cork stopper, allowing Ruijsch to remove the

Fig. 6. Specimen nr. 196, an injected child's hand with an underdeveloped thumb and abnormal hair growth on the forearm. Photographer R.I. Tamchenko. ©Military Medical Academy, Saint Petersburg, 2020. Published with permission.
Рис. 6. Препарат № 196, инъецированная детская рука с недоразвитым большим пальцем и аномальным ростом волос на предплечье. Фотограф Р.И. Тамченко. ©Военно-медицинская академия, Санкт-Петербург, 2020. Публикуется с разрешения.

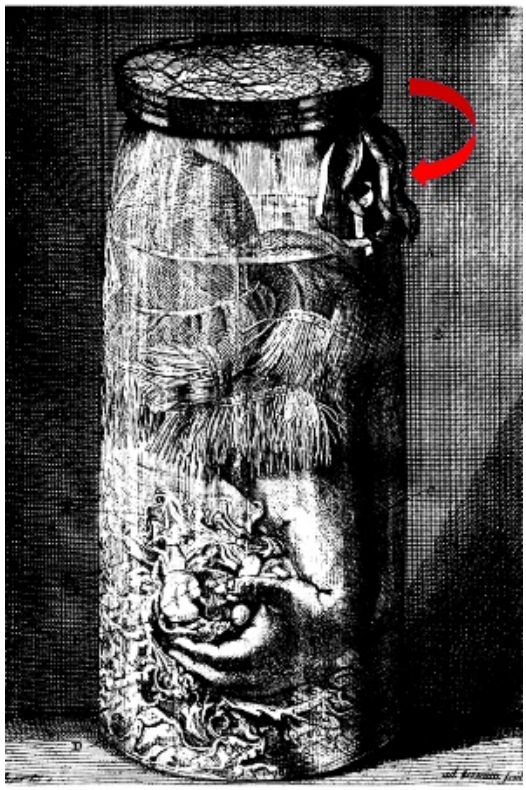

Fig. 7. The jar contains an arm of a small child, which holds a polypous mass. The wound of the arm is lined with linen and fringe. The top of the glass jar is lined with a membrane whose arteries have been injected with a red waxy substance. The whole is tied with a ribbon to close it [37]. In the public domain.
Рис. 7. В банке находится рука маленького ребенка, которая держит полипозную массу. Рана на руке выстлана льном и бахромой. Верх стеклянной банки затянут перепонкой с инъецированными красным воскообразным веществом артериями. Банка перевязана лентой [37]. В общем доступе.

specimen for further dissection or demonstration to an audience [18]. For more permanent closure, the jars were closed with a round slab of slate. These were sealed with wax. This sealing wax probably consisted of beeswax, carnauba wax or colophonium, minium (red lead) and chalk powder. To prevent the lid from loosening, a pig or sheep bladder was wetted, stretched over the top of the jar and secured with a thin string (Fig. 7) [34].

This method gave a relatively long-lasting, tight and secure seal. Some covers were heavily decorated with other natural products (dried plants, corals) [23], but this was very infrequently the case [18]. Due to the properties of the lids and sealing, combined with the environmental conditions (considerable swings in temperature), the resulting leakage around the stopper and evaporation of the preservation fluid will have required the conservators of later generations to move the specimens to new jars and use better plugs. The requirement to continuously top up the preservation fluid makes it unlikely that the present fluid contains any traces of the fluids initially used by Ruijsch. Mulder et al. have already demonstrated the near absence of traces during their restoration of the Ruijsch collection, kept in the Kunstkamera in 2001 [26]. Therefore, we did not endeavour to further research the fluids we encountered during this part of our restoration.

The formability of Frederik Ruijsch's techniques is demonstrated by the excellent conditions of those specimens that had not been affected by the conservation errors made by later generations. This holds for the nine samples that were still stored in alcohol. The erroneous exchange of the ethanol-based fluids of Ruijsch for turpentine and formaldehyde affected four specimens. The result was tissue shrinkage, darkening, damage to the mercury-stained vessels, and decolourising of the preservation fluid. Given the pieces' historical importance, we decided to proceed with the preservation and used an individualized approach for each specimen to improve conditions without additional damage.

Simmons states that many problems with fluid-preserved specimens are now recognized, but there is very little data to resolve them [30, 31]. This is largely because the care of scientific specimens is communicated as an oral tradition,

almost solely on custom. There are few scientifically tested, rigorous procedures for caring for wet collections [30, 31]. Particularly the transfer of specimens between fluids is a delicate process. This is particularly true for specimen inventory nr. 196, that was transferred from a formaldehyde-containing fluid to an ethyl alcohol-containing fluid. We applied sequential steps with 20% increases from 30% to 70% over several days to avoid too significant differences in osmolarity and, thus, osmotic pressure, which could lead to tissue damage. Because of its binding to tissue, formaldehyde is not easily rinsed by tissues and may be released into the alcohol solution for years. Clouding of the solution and forming formaldehyde needles may occur [31]. Furthermore, the appearance of paraformaldehyde may result in acidification of the solution and tissue damage. The only solution to these sequels is a repeated rinsing of the specimen with water of ethyl alcohol and an exchange of the liquid in the jar with fresh alcohol.

Discussion

There were several reasons for conserving organs, tissues, and whole-body specimens during the Ruijsch period. It was difficult to obtain human materials. Public opinion was very much against autopsy, and often illegal methods were used to obtain human material [6]. The material would rapidly decay without treatment, particularly in summertime. Conservation before dissection allowed stepwise dissection until achieving the desired stage [18]. Further conservation into a dried or wet specimen, using enhancing techniques like injection with coloured wax, would allow specimens to be suitable for permanent display. Ruijsch added decoration with artefacts from nature, lace, and moralistic texts, adding more to the artistic value of the specimen and lessening the raw effects of an anatomical display. His contemporary Govert Bidloo objected to the life-like and decorated approach of Ruijsch, as the presentation would be only a part of the dissection, thus failing to show the actual image of the body [22]. Similarly, Hunter (not a contemporary of Ruijsch but somewhat later) argues that “both wet and dry preparations share the defect of not resembling the body in its natural state” [22]. Preparation, injection, and conservation have a long history in which Ruijsch plays a prominent part due to his skills, which made him a scholar to be followed by many.

The wet and dry objects carried economic value, as the specimens were displayed in his Cabinet on the Nieuwerzijds Voorburgwal in Amsterdam, open to the public against payment and, as such, a source of income for Ruijsch [17]. Ruijsch treated his techniques and the composition of the fluids he used as his intellectual property, concealing it from others. He sold his secret to Peter the Great, and the extensive collection of objects later placed in the Kunstkamera. The composition of the fluid was later disclosed after the death of Peter the Great by Rieger, but the specifications appear to be far from precise [5]. It can be argued that the vast investments Ruijsch made throughout his life in his collection were not solely for scientific purposes. Margocsy [21] states that Lodewijk de Bils (1624–1669) (whom Margocsy claims to be the inventor of the methods) and Ruijsch intended to maintain a monopoly over their methods of preparation. None of their printed works ever disclosed how the specimens were produced. He argued that the discussion between Bidloo and Ruijsch (see earlier) was also connected to the world of commerce. While both anatomists owned anatomical preparations, only Ruijsch’s specimens could be considered real commodities. Ruijsch’s collection was sold for 30,000 Dutch Guilders to the Tsar, in 1716 comparable to the price of 6 houses in Amsterdam. Bidloo had only a meagre set of specimens because he invested his energies into producing a luxury atlas, which he hoped to promote by denigrating the competing representation by Ruijsch.

Conclusion

We present our findings of the so-called small collection of wet and dry Ruijsch specimens held in the Department of Regular Anatomy of the Military Medical Academy in Saint Petersburg, which is used for educational purposes within the Academy. These kinds of collections are not always without ethical criticism, but they give a good insight into the historical collection of human remains, and the scientific knowledge at the time of collecting [8]. The department staff will further conserve the collection. This collection has significant historical value, and its acquisition fulfilled Peter the Great's wish to educate Russian students. This collection founded the path for obtaining the complete collection of Frederik Ruijsch by Tsar Peter in 1717, subsequently installed in the Kunstkamera [12].

Ethics approval and consent to participate

Permission has been given by the Military Medical Academy SPB for images of human material that cannot be traced back to individuals.

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