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Twenty-six renal aphorisms of Santorio Santorio (1561-1636)

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Introduction

In 1614, the printing house of Niccolò Polo in Venice published a slender book (12 mo) entitled Ars Sanctorii Sanctorii de statica medicina, sectionibus aphorismorum septem comprehensa, later known as Frontis di de Satica (Art of static medicine) (Fig. 1). The second edition was published "apud Marcum Brogiollum". De statica, written in elegant Latin, was structured in 7 chapters: perspiration insensibilis, air and waters, foods and drinks, sleep and waking, movements and rest, sexual activity, and emotions, which correspond to the 6 nonnaturals of Galen. Therein for the first time, diseases were discussed as the end effect of obstructed perspiration (a function occurring through pores). The author (Santorio Santorio) had been studying that excretion for over 30 years with the use of a weighing chair, on some 10,000 persons including Galileo Galilei. A great part of the data had been obtained through self-experimentation. The frontispiece of De statica medicina showed a man sitting before a table, on a weighing instrument at the end of his meal, thus checking his weight.

Santorio Santorio

Santorio Santorio or Sanctorius (1561-1640) (Fig. 2), was born in Capodistria, in the Republic of Venice, now Koper, in Slovenia. He was hired by the University of Padua on October 6, 1611, as professor of theoretical medicine (1st chair, the most important). At the time of the publication of *Frontis di de Satica* he was well known in the Republic of Venice, having published in 1603 (Venetiis, apud Franciscum Barilettum) the *Methodi vitandorum errorum omnium qui in arte medica contigunt libri quindecim* (Methods to avoid all the errors in medicine, 15 books) and *Commentaria in artem medicinalem Galeni* (Commentaries on Galen's medical arts), in 1612 (Venetiis, apud Franciscum Somascum, *in folio*). Both books introduced innovative instrumentation in medicine. The former reported on the *pulsilogium* (a stop clock to measure the pulse), the latter on the thermometer, probably inspired by Galileo, but bearing a scale to measure temperature. Santorio was a much sought after physician in Venice with a large clientele and was revered, thanks to his expertise on Hippocrates, Aristotle, Galen and Avicenna. He was linked to the most advanced group of innovators in Venice with whom he used to meet in the Morosini Palace. He admired and respected Galileo, and befriended Paolo Sarpi (1552-1623), the Servite friar advisor of the Republic, Giovanfrancesco Sagredo, Agostino Da Mula (1561-?) and the cream of the intelligentsia in Venice. In the Morosini Palace, which was more than an academy – a place where the future was inspired. The circle was presided over by Francesco Morosini.

De medicina statica met with an extraordinary success. It had


ARS
SANCTORII
SANCTORII
Olim
In Patauino Gymnaſio Medicinæ
Theoricam ordinariam primo
loco profitentis.
DE STATICA
MEDICINA
Et de reſponſione ad Staticomaſticem.
APHORISMORVM
Sectionibus ſeptem comprehenſa.
CVM PRIVILEGIO.
VENETIIS, MDCXXXIV.
Apud Marcum Antonium Brogiollum
Superiorum Licentia.

Fig. 1

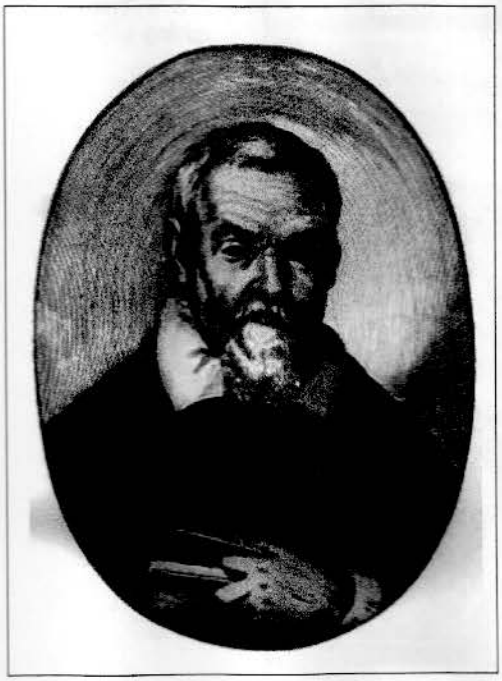

Fig. 2

many Latin editions, was translated into Italian, French and English, and was the most translated work for more than 1 century. It elicited the appreciation of Giorgio Baglivi (*Canon de medicina solidorum*), Giovanni Borelli (*De motu animalium*), Marcello Malpighi, Archibald Pitcairne (*De curatione febrium*), Luigi Bellini (*De missione sanguinis*), Hermann Boerhaave (*Institutiones medicae*) and Albrecht von Haller (*Bibliotheca anatomica*, and *Bibliotheca medicinae praticae*). In addition, Santorio was immortalized by 3 entries in the *Encyclopédie* of Diderot and d'Alembert.

De statica medicina promoted the birth of a medicine based on weighing in the Lower Countries (De Gorter, *De perspiratione insensibili Sanctoriana-Batava tractatus experimentis propriis in Hollandis...*, 1725) and England. Henricus Regius, professor of medicine at Utrecht, in 1654 expressed his pride to have learned about the weighing in Padua when he was a medical student in 1622: "*experientia statica Sanctorii praeceptoris quondam nostri.*" It was also commented on by Martin Lister and John Quincey.

The book lost its scientific appeal with Lavoisier and Seguin (1790), who, in a contribution to the Royal Academy of Sciences in Paris pointed out that "Santorio obviously lacked knowledge about principles to be developed after him, in centuries to come, namely the principles of respiration as well as the formation of water and carbonic acid" (1). However this did not prevent its further dissemination, rather it became a topic for research since it became apparent that the book introduced a new vision of medicine, a medicine based on weight and measurements, on precise assessment with instruments. No longer a qualitative imprecise approach, but a transition from the world of "just about" or "rough-and-ready observations" to that of precision (2). The book disclosed the creativity of a man capable of devising and using at bedside precise instruments, a scientist capable of guiding the transit from qualitative experience to quantitative experimentation in man and in animals, and, as expressed by Arturo Castiglioni, it represented "the foundation stone upon which has been constructed the entire structure of modern medicine," 15 years before Harvey's *De motu cordis*.

Santorio and *De medicina statica* have been extensively studied (3-14) by great historians of medicine and science: Arcadio Capello (1750), Pietro Stancovich (1829), Modestino del Gaizo (1889, 1890) who brought Santorio into the limelight, Arturo Castiglioni (1920), Mirko Drazen Grmek and Giuseppe Ongaro (2001). Ralph H. Major (1938) provided a list of scientists inspired by *De statica*, Nancy Siraisi discussed the teaching method (1987), Garabed Eknoyan identified him as precursor of metabolic balance studies (1999) and Shigehisha Muriyama discussed it

Fig. 3 - The weighing balance.

in terms of the long-lasting fear of excrements (2008). Finally, Ettari and Procopio (1968) arranged a superb list of documents concerning Santorio.

Weighing experiments

Santorio, through accurate weighing of body weight (Fig. 3), foods and drinks, feces and urine, observed that in 1 night are evacuated 16 ounces of urine, 4 ounces of feces and 40 or more ounces of insensible transpiration. So transpiration, known for more than 2 millennia, was measured for the first time, and it was shown that it varied according to the natural characteristics of region, place, age, diseases, foods and other non-natural things of Galen (Aphorism VII, Section 1) (15).

As pointed out in a letter to Galileo accompanying Santorio's gift to him of a copy of the *De statica medicina*: "This art I have invented is very important, as it is evident since it measures insensible transpiration, which when altered or obstructed, according to Hippocrates and Galen is the origin of all diseases." Furthermore, in the note to readers he wrote: "It is new and unprecedented in medicine to exactly weigh perspiration, no philosopher, no physician dared to study the topic before. I did the attempt and after thirty years experience I have brought this art to perfection (if I am not mistaken), which I present in the form of aphorisms." Measurements of weight, intakes and excretions represent therefore the basis for a medicine based on equilibrium, on the addition of what is lacking and elimination of what is in excess, as postulated by Hippocrates in *De flatibus* (On flatus).

So, nutrition is important. Control of intakes is the tool and must be associated with measurement of excreta. Measurements of weight, intakes and excretions were therefore the *condicio sine qua non* for a medicine based on equilibrium, on the addition of what is lacking and elimination what is in excess as postulated by Hippocrates in *De flatibus (*On flatus).

Nutrition was a very important body function since from it originates the flesh of the body. Control of intakes is the tool and must be associated with measurement of excreta. For Santorio, he who knows the time course and the quantity of perspiration, can decide how much must be added or subtracted to keep the balance (Aphorism III, Section 1).

A twofold role for the steelyard chair

The steelyard chair had a twofold role, that of calculating the perspiration and making a decision about food and drinks to be ingested. The ultimate goal (Aphorism LIV, Section 1) being that to enjoy long-lasting well-being one shall know the amount of perspiration. It should be assessed individually in the morning after a copious evening meal (suppose it be 50 ounces) and following abstention from foods in the evening meal after a moderate lunch (suppose it be 20 ounces). Thereafter one shall adopt a moderate regimen of food intake and keep a moderate level of nonnatural conditions "in order to reach every day the intermediate point between fifty and twenty, that is thirty-five ounces. In this way you will live the healthiest and longest life, rather hundred years." In conclusion, achieving and maintaining a good state of health is a matter of appropriate nutrition capable of replacing losses and subtracting the excesses as well. A continuous monitoring of body weight, foods, drinks, urine, feces and perspiration became therefore the fundamental factors to be taken into account to achieve well-being, which in the ultimate analysis is represented by the balance between intakes and excretions (16).

Santorio's renal aphorisms

We report here 26 Santorian aphorisms of nephrological interest from *De statica medicina*, by section (in Arabic) and number (in Roman), according to the 1636 edition translated by Ongaro in 2001 (7). They are divided into sections: 1. on physiology, 2. on prognosis, 3. on therapeutics, 4. on hydrops, 5. on kidney dysfunction after coitus, 6. on prevention and 7. of general interest.

On physiology

[Section 1, Aphorism LIX]
In one night a maximum of sixteen ounces of urine are passed along with four ounces of excrements digested through the intestine, and forty ounces or more through invisible perspiration.

In 12 nocturnal hours, 16 ounces of urine are passed along with 16 ounces of feces and 40 ounces or more of perspiration. According to Ongaro (9), the data were in small Venetian ounces (1 ounce = 25 g), corresponding to 880 g of urine, 200 g of feces and 2,000 g of perspiration. So, the most important excrement is represented by perspiration. This aphorism does not only provide an example of the factors granting constancy of body weight but also efficaciously explains the birth of an approach to medicine based on measurement, as devised by Santorio. The details for the factors on which body weight changes depend, are very important if one considers that physicians used to modify them by emetics, purges, enemas, diuretics, according to quantitative medicine as outlined by Santorio. One should note that transpiration, the most important evacuation in keeping a stable body weight, is twice the sum of all other excretions. The aphorism also anticipates the concept of overnight urine frequently used nowadays to avoid the difficulties connected with 24-hour urine collections.

[1, LXV] *Even the bodies of healthy people who eat parsimoniously every month increase their weight of about one-two pounds and go back to their usual weight at the end of the month, as occurs in women, after a crisis causing either an increase in urine volume or an increase of its turbidity.*

A (circadian) monthly increase of 1-2 pounds in body weight occurs even in people who eat moderately. The increase is followed by an identical decrement, as it happens in women. The reduction is due either to an increased urine volume or to increased urine turbidity (containing more salinities arising from foods). Urine by its volume and salt content proves a strong factor in granting body weight balance. Thus urine is the key factor to restore body weight balance.

[1, LXVI] *Before the monthly crisis which occurs after sleep, one suffers of heavy head and weakness of the body, then everything stops following an increased urine voiding.*

This aphorism, to be read as a corollary of the previous one, points to the benefits of a transient polyuric state to heal heavy head and body exhaustion (due to the plethoric state).

[1, LXXXIX] *Vomiting diverts urine and insensible perspiration.*

Following vomiting, urine and perspiration are reduced or absent. A redistribution of excreta (and probably of the functioning of the organs where they originate) occurs following dehydration due to vomiting.

[1, XIII] *In persons excreting sensible evacuations in excess to normalcy, transpiration is below normal.*

We find again the balance between fecal and urinary volume and perspiration. The latter declines when feces and urine increase. In other words: an excess of sensible loss is detrimental to good health.

[1, XCIV] *Those who urinate more than they drink have low or no perspiration.*

Once again a balance study. The aphorism indicates that perspiration is reduced when urine volume exceeds drinks (and probably it may be seen also as a caveat for the difficulties in restoring it after blockade). A failure in finely digesting humors (a failure of the third digestion) causes obstruction of the excretory channels, which results in increased urine volume.

[1, CXXV] *Whereas the contraction of the sphincter shuts the bladder and retains urine, its relaxation dilates it and let urine pass.*

The aphorism is very precise regarding the bladder sphincter. Its contraction impedes the transit of urine, its relaxation allows it. (A general rule for all sphincters.)

[3, XIV] *Robust persons discharge their foods mostly through insensible perspiration, those less robust by urine, those who are weak for the major part through corruption of the chyle (increased stool).*

Robust persons (also for those with large skin area and body mass) are able to finely break solids generated in the digestion so they may be excreted through perspiration (a demanding process), those less robust will be able to digest them up to the point they can be excreted through

the kidneys, while the weak persons are unable to break them and pass them in faeces.

On prognosis

> [1, X] *The body keeps its health state when its weight is stable without an increase of sensible evacuations. However, when stability of weight is preserved through an increase of the excretion of urine and faeces in excess of the usual, then a decline from the former health takes place.*

The healthy state is characterized by stability of body weight which depends on a stable urine and fecal output. When body weight is kept constant by increased urine and/or fecal excretion, a deviation from the previous healthy state is foreseen. The aphorism stresses that the constancy of body weight must be achieved by constant excretion of sensible losses; however, when constancy of body weight is achieved by means of polyuria or diarrhea, an initial deviation from the previous healthy state is present.

> [1, XIV] *Discharging thick stool, urinating or sweating more than appropriate and a low perspiration are harmful.*

The excretion of thick feces, an increase in urine output and sweating associated with a low perspiration are dangerous because of their association with a state of dehydration, the pathogenesis of which Santorio discloses here.

> [1, XLIII] *When weighing points to retention of what usually perspires, not followed a few days later by an increase of sweat or urine, from this you will understand that retained matter will cause a future corruption.*

When the scale discloses retention of perspiration not followed, days later, by increased sweating and urine volume, a disease due to increased body fluid must be anticipated (dropsical state).

On therapeutics

> [1, XLVIII] *A small dose of Cassia does not divert perspiration and does not impair the strength, it just evacuates useless weight. Other drugs evacuate more by reaching more peripheral parts thus rendering the body lighter, and intestine and bladder are dried up, however foods and drink will fill the empty channels and thus the body will increases.*

Cassia, a bland laxative, does not impair perspiration and strength since it clears inert fluid. Stronger drugs reaching remote passages render the body lighter and cause anuria and absence of feces. However, food and drink refill the empty channels and body weight is resumed. The conclusion is that cathartics, and diuretics (as well as emetics, enemas, diaphoretics and bloodletting) do not prevent disease.

> [1, LXXXIV] *Old people die because of coitus, low body temperature, excessive drinking and eating, acting like young, feeling angry, and excessive activities.*

Old people die because of sexual activity (cerebrovascular accidents?), the typical reduction of the body temperature (due to a reduced metabolism), excessive use of spirits, immoderate food intake, outbursts of anger and excessive work.

> [1, LXXXV] *Old people die before reaching a decrepit age because of impaired excretory capabilities. When they drink in excess they perspire and urinate less. The remedy consists in eliminating the excess.*

Old people die before becoming decrepit because of weakened excretory functions. Thus following a heavy drink, perspiration and urine are contracted. The appropriate cure consists in avoiding an excessive intake.

> [1, XCI] *Warming the knees by moves prevents cold feet, grants good sleeping, increases transpiration and reduces urine volume.*

Physical exercise warms the joints, prevents cold feet, promotes a good sleep, increases perspiration, and reduces urinary output. (This further confirms the inverse relationship between perspiration and urine volume.)

> [3, LXVI] *An abundant sweating or an increased urine voiding after hard drinking indicates either a robust constitution or a great weakness.*

After a hard drink, robust people sweat or urinate more since the solids to be excreted cause contractions, which leads to elimination of the excess fluid, while (by contrast) weak people, because of the relaxed state of fluids, will experience a retarded recovery.

On hydrops

> [1, XCVI] *In dropsy, water is not eliminated from the abdomen since its dryness and consistence obstruct perspiration.*

Dropsical persons are unable to excrete water from the abdomen because of the dryness and hardness of the abdominal wall, which lead to obstructed perspiration and fluid stagnation.

> [7, XIII] *It is unimportant that the perspirable matter retained by melancholy persons is cold and sharp or hot; this is typical for the liver in feverish hydropics, which means cold in comparison to the natural heat and hot in comparison to the heat originating externally.*

The aphorism confirms the vast Sanctorian knowledge about humors in melancholy people. The quality of perspirable matter (cold and sharp or hot) may not be important since it is not different from what happens in dropsical feverish people. In that case, the perspirable matter is cold in comparison with the heat generated in the body and is hot in comparison with the heat generated externally.

On kidney dysfunctions after coitus

> [6, IX] *Coitus is not harmful as attested by the usual urine digestion, bodily agility, the easier breathing, and the stability of body weight if quality and quantity of intakes are kept constant.*

Coitus does not cause injury as attested by the normalcy of urine concoction and improved bodily functions (agility, body weight constancy, easy breathing), provided that quality and quantity of intakes are kept constant.

> [6, XXIII] *Coitus heats liver and kidneys, since the heat generated perspires at a lower extent; however, it colds [sic] the stomach, the brain and the heart since the heat flows through channels opened in other organs leading to recovery.*

Sexual activity increases heat production; however, its balance is maintained notwithstanding the excessive production which is eliminated through a dilation of channels in other organs.

> [6, XXIV] *Immoderate coitus induces biliary affections of the liver, nephritic disease in the kidneys (in renibus nephriticum affectum), indigestion in stomach, catarrh [inflammation] of the brain, palpitation and syncope in the heart.*

An excessive sexual activity causes biliary disease, nephritis, gut indigestion, brain inflammation, and heart palpitations and fainting fits. Please note that in Santorio's times, the term *nephritis* had not yet been defined, and some translators refer to sands or stones.

On prevention

> [5, XXX] *Going by carts is the most violent motion which renders perspirable even the matter not yet concocted, but it affects also solid body parts, especially the kidneys.*

This aphorism points to the risks of going by coach on stony roads which, straining the viscera, forces the saline parts secreted from blood into kidneys, causing pains. Horseriding or going by coach at that time was considered risky since it was associated with stone movements within the urogenital tract. An example is to be found in Montaigne's *Essays* and *Travel Journal*. However, here Santorio introduces another perspective. According to him, the use of the coach was associated with strains on the kidney thus favoring the transit of salts from blood into kidneys.

Of general interest

> [1, LXI] *Why doctors in any disease do take care to ease evacuations through the intestine or with urine and rarely do they care about insensible perspiration?*

Physicians are very strange persons. They care about urine and bowel excretion but never look into perspiration. They are negligent. Given that perspiration is the most important bodily evacuation, they should start by assessing it.

> [1, CVIII] *In robust persons thick humours go through the narrowest roads, as it is evident for fat eliminated with urine, or in the case of hydromel injected in a chest wound which pass through invisible channels.*

Alternative, tight excretory routes may be used so that gross humors may trespass tight passages as is attested by the presence of fat in urine or by the hydromel injected into a thoracic wound. They pass through invisible channels.

> [2, XIX] *Usually weak people transform retained perspirable matter into urine in winter, robust persons in summer.*

Weak people in winter time are able to break solids so that they pass in urine. By contrast, this capability is achieved in

summer by robust people who, in that season, because of the heat, are unable to break these solids to be perspired.

> [3, XXVI] *The retained transpiration caused by melons is usually eliminated through urine and sweat.*

The aphorism should be analyzed taking into account aphorism 3, XXV, which reads: "Melons reduce perspiration and cause a 25% reduction of its quantity." It indicates that melons cannot be broken up fine and because of their size are for the most part excreted in urine or sweat and, to a lesser extent, through perspiration.

Discussion

De statica should be seen as a list of suggestions on appropriate nutrition and on the destiny of the residuals (bad humors) generated during its process. By adopting those precepts, one could assess his state of well-being, foresee imminent diseases and take adequate measures to prevent them by acting on foods and drinks as well as on excretions.

On urine volume

In the above aphorisms, urine represents a very important bodily excretion in health and disease. Santorio introduces us to the concept of overnight urine, when he writes (1, LIX) "spatio unius noctis" (in one night) and points out that a total of 16 ounces of urine are passed, for a total of either 400 g or 636 g according to the unit, the small ounce being of 25 g and the great 40 g. We are inclined to think that the latter unit more appropriate since daily urine output with the former it would average 800 ml/day which is a scanty volume for the foods and the drink in the diet in those times.

On urine physiology and unphysiology

Urine is excreted from the bladder through a perfect mechanism based on a particular arrangement of the fibers (1, CXXV), it corrects physiologically the small changes in body weight (1, LXV), is in relation with food intakes and transient increase cures head heaviness caused by increased retention (1, LXVI). Urine is reduced after vomiting (1, LXXXIX), is indirectly correlated with perspiration (1, XIII and 1, XCIV), it carries out from the body solids of mean size generated during digestion (3, XIV). A stable weight by constant urine and fecal volume attests a healthy state, a stable body weight following a drug-induced polyuria does not (1, X). Polyuria is harmful (1, XLIII), as it is an increased body weight not followed either by increased urine excretion or increased perspiration, or thick stools. Bland cathartics are useful; stronger cathartics are unhealthy since they reduce urine output and do not prevent disease. In old people, urine volume does not increase with excessive water intake (reduced diluting power), and there is a proportion between drinkables and urine volume (3, LXVI). Hydrops is linked to liver disease. Moderate coitus does not affect the quality of urine being normally digested (6, IX); it increases heat production in the kidney which is substituted by other channels (6, XXIII). However, its excess may cause *"in renibus nephriticum affectum"* (in the kidneys a nephritic disease). Finally, eating melons causes polyuria or increased perspiration (3, XXVI) and going by carts may be harmful since it moves stones in the kidney (5, XXX). The last aphorism helps the reader to understand the various episodes of renal colic Michel De Montaigne described in 1774 in his *Travel Journal.*

About toxics arising from nutrition

Alimentation, as early as the 5th century BC, has been seen as the cause of residuals which had to be excreted. For example, in the old Greek papyrus known as *Anonymus Londinensis* (17), we learn that "diseases arise because of residues from nutriment," and as we do in the writing of Euryphon of Cnidus (mid-5th century BC), for whom diseases arise by "inability of bell to discharge, thus residues of nutrients are produced which cause disease." The same holds for Nynias (300 BC) the Egyptian physician. Erodicus of Cnidos (c.500-c.430-420 BC) agrees on the importance of residues which are generated "when men take in nutriment without previous exercise." For Alcamenes of Abydos (5th century BC), "residues rushing up to head, and being disseminated throughout the whole body produce disease in it." Furthermore, Thimoteus of Metapontum (400 BC) made the point that "whenever the head is not healthy it brings on disease by passages being blocked. For when these are blocked, the residue mounts to the part about the head and for while remains there because has no passage." But later on it forces passages and reaches the part of the body. Hippon of Croton (5th century BC) identifies the causes of disease in the drying of moisture for which we perceive and live, thus old people are diseased, being dried up because of excess of heat or excess of cold. For Trasymachus of Sardis (350 BC), diseases were due to blood corruption which turns it into bile or pus.

However, all of the history of Western medicine is centered on bile and phlegm, the harmful humors which have to be

evacuated (13), starting with Hippocrates. The latter, in *Disease I*, writes

> All diseases come to be, as regards things inside the body, from bile and phlegm, and as regards external things, from exercise and wounds, from the hot being too hot, the cold to cold, the dry to dry, and the wet too wet. And bile and phlegm are formed in things as they come to be and almost exists, in greater or lesser quantities, in the body, as they bring about disease, both those arising from food and drink and those from excess of hot and cold. (18)

On perspiration

As reviewed by Bylebyl (19), Renbourne (20) and Ongaro (7), perspiration had been known for centuries before Santorio. The Greek doctor Aegimius of Elis (who according to Galen authored a book *On Palpitation*), opened the field, whereas Erasistratus (3rd century BC), is credited, according to the Greek papyrus *Anonymus Londinensis* (17) with its demonstration in animals (birds). For Erasistratus, air entering into the body with respiration:

> serves no cooling function whatsoever. Rather it supplies the pneuma required in physiological processes, replacing the pneuma that has been consumed or lost through visible transpiration, via the epidermal pores. From this point forward, the pneuma circulates through the body as it would in an almost perfectly sealed pneumatic machine (save only for the transpiration of the skin). (21)

However, it all started in the second half of the 5th century BC when Empedocles of Acragas (504-443 BC) pointed out that the whole body – not only the lungs – breaths in and out, through pores, a process for which the exact word was *anapnoe* (respiration). "All beings have bloodless tubes of flesh spread over the outside of the body, at the opening of these the outer layers of the skin are pieced all all over with the close set ducts, so that the blood remains within, while a facile opening is cut for the air to pass through" (22). According to Harris (23), the theory "that both heart and arteries draw in *pneuma*, not only through pores from the surface of the skin" was adopted by the Alexandrian physician Herophilus (330/320-260/250 BC).

The existence of perspiration was also recognized by Asclepiades (1st century BC), Celsus (1st century AD). Galen (2nd century AD) in *De Facultatibus naturalibus* wrote,

> What we drink is turned into urine with the exception of what is excreted with faeces, sweat, or insensible perspiration. This is evident when taking into account the quantity of urine passed daily. This can be ascertained, mainly in winter, in resting people drinking more than needed, especially when wine is light and fluid. Those people immediately pass a quantity of urine slightly less than the quantity just drunk. This was known to Erasistratus.

However, at that time and for many centuries to come, the distinction between sweat and perspiration was not clear. For Galen, however, sweat is that passing as droplets, whereas "in the insensible perspiration some of denser excrement is eliminated." For Galen (*Liber de alimento*) perspiration occurs through the skin, thus he spoke of *diapnoé* (*De Hyppocratis et Platonis placitiis*) occurring on the whole surface of body skin (*De methodo medendi*). Galen's idea about perspiration was confirmed by Leonardo da Vinci and Ambroise Parè (24). Leonardo Botallo (1519-1588) (25) in turn supported the notion of a human body behaving like a syphon and loosing continuously substance through perspiration and draining new material from veins, a concept with Greek roots.

However, nobody before Santorio dared to measure perspiration. He was aware of this, since he wrote: "It is a new unprecedented event to exactly weigh insensible transpiration, and before me no philosopher, no physician dared to study this aspect of medical doctrine. I was the first to attempt and by reasoning and thirty years experience I have brought to perfection (if I am not mistaken) this art which seemed appropriate to present under the form of aphorisms," as appears in his letter to Galileo (15).

Santorio's certainties in his findings: differences with Harvey

It is a truism that Santorio during 30 years of experimentation nurtured the certainty of his theory about perspiration, which he finally published in 1614. He derived his conviction first of all because the vastness of his enquiry and, secondly, by the control he had made of many variables and the possibility to provide results numerical form. This is well expressed in Aphorism no. VII, in Section 1: "The variability of natural characteristics, country, season, age, diseases, foods and the remaining non natural things." Thus he was pleased with his experimental protocol and took pride in the novelty of his discoveries and in the procedure used. He had an idea, had taken all the time needed to verify it on a huge number of persons, even resorting to his own body when something did not fit with his mathematical model. In this he was at variance with Harvey who apparently felt less certain regarding

the value of his experiments – as Jerom J. Bylebil remarked with originality (19). Harvey in Chapter 9 of *De motu cordis* wished that someone in the future might replace his arbitrary figures with the real numbers and devise a thorough program of experiments. There Harvey introduced the variability of blood movements "according to temperament, age, external and internal causes, and the things natural, as well as the non natural such as sleep, quiet, food, exercise, passions of the soul, and the like."

Perspiration: a tool to understand dehydration

Body fluid derangements has been one of the seminal topics driven by those interested in nephrology, before the advent of therapy for acute and chronic renal failure. Furthermore, it has been stated that the major impulse to the specialty of pediatric nephrology was represented by therapy of dehydration (26) which has its roots in the birth of medicine based on measurements. Obviously all started in Padua with Santorio's assessment of insensible perspiration. Three hundred years were needed to understand that the stools of persons with cholera had a composition not different from that of blood and the possibility to manage them with intravenous watery solution of sodium chloride (27). Such results were confirmed in 1892 by Arnaldo Cantani during an epidemic of cholera in Naples.

Effects of *De statica medicina* on medical practice

De medicina statica had a great influence on medical practice. It is not difficult to understand that, in addition to a safe amount of foods and drinks, a whole armamentarium was needed to reach the needed level of perspiration and to cure the obstructed perspiration. This could be accomplished through appetizers, emetics, antidiarrheals, purgatives, enemas, diaphoretics, warm and cold baths, warm punches and bloodletting. This is not taking into consideration the fear of cold temperatures and humidity and clothing which could block perspiration.

Why a new English translation of Santorio's renal aphorisms?

There are at our disposal excellent historical translations of *De medicina statica*, the most famous being that of John Quincy dated 1720 (28). However, we think that every generation has the right to retranslate the works of art in order to rethink them and to add new value to their meaning. The new look shall occur not in opposition to historical translations but following an hard confrontation with them. We were very much comforted by the preface to a recent translation of Paul Valery's *Eupalinos: Or the Architect* (29), pointing to the fact that translation is a virtually infinite process, never reaching an end, susceptible of variations and establishing a dialogue with the original works as well as with previous translations. We have followed – as suggested by Ongaro in the 1534 edition (Venetiis, Apud Marcum Antonium Brogiollum), the last editions appeared during Santorio's life thus "presumably revised by the author" (7).

Of self-experimentation and adequacy of experiments

Santorio was an example of self-experimentation (30, 31), in this perfectly adhering to Galen (32) who experimented on himself with the Lemnian Earth (*De simplicium medicamentorum temperamentis et facultatibus*), vinegar as an antidote to thapsia (*Liber simplici medicinae*) and plant remedies to be used in patients with nervous damage (*De composition medicamentorum per genera*). Santorio gave to self-experimentation a great contribution by sitting on the static chair and collecting a huge number of observations under various experimental conditions. In this he anticipated many famous scientists of the 20th century including Werner Theodor Otto Forssman who introduced a catheter into his heart in 1929, and Carmelo Giordano who studied the effect of amino acid diets in a 60-day experiment in 1960.

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REFERENCES

1. Farina P. Sulla formazione scientifica di Henricus Regius: Santorio Santorio e il De statica medicina. Riv Crit Stor Filos. 1975;30:363-400.
2. Koiré A. Dal mondo del pressapoco all'universo della precisione. Torino: Einaudi; 1967.
3. Capello A. De vita cl. Viri Sanctorii Sanctorii, olim in Patavino Gymnasio Medicinam Theoricam in primo loco profitentis. Accedit oratio ab eodem Sanctorio habita in Gymnasio Patavino dum ipse primarium Theoricae Medicina eplicandae munus auspicaretur. Venetiis apud Jacobum Thomasinum; 1750.
4. Stancovich P. Biografia degli uomini distinti dell'Istria. Trieste: presso Gio. Marenigh; 1829:235-259.
5. Del Gaizo M. Ricerche storiche intorno a Santorio Santorio ed alla medicina statica. Napoli: Resoconti della Reaale Accademia Medico-Chirurgica di Napoli; 1889.
6. Del Gaizo M. Alcune conoscenze di Santorio Santorio intorno ai fenomeni della visione ed il testamento di lui. Napoli: Atti dell'Accademia Pontaniana; 1891:21-48.
7. Castiglioni A. La vita e l'opera di Sanorio Santorio, MDLXI-NDCXXXVI. Bologna: Licinio Cappelli Editore; 1920:1-90.
8. Grmek MD. Santorio j njegovi aparati i istrumenti. Zagreb; 1952.
9. Ongaro G. Santorio Santorio: La medicina statica. Firenze: Giunti; 2001:1-187.
10. Major RH. Santorio Santorio. Ann Med Hist. 1938;10:369-381.
11. Siraisi NG. Avicenna in Renaissance in Italy. The "Canon" and medical teaching in Italian Universities after 1500. Princeton, NJ: Princeton University Press; 1987:120, 206-211.
12. Eknoyan G. Santorio Sanctorius (1561-1636): founding father of metabolic balance studies. Am J Nephrol. 1999;19(2): 226-233.
13. Kuriyma S. The forgotten fear for excrement. JMEMMS. 2008;38:413-442.
14. Ettari LS, Procopio M. Santorio Santorio: la vita e l'opera. Roma: Quaderni Instituto Nazionale della Nutrizione; 1968.
15. Santorio Santorio. Letter to Galilei dated February 9, 1615. Biblioteca Nazionale di Firenze. (Mss. Gal, P.VI, T, Cartella 218).
16. Dacone L. Living with the chair: provate excreta, collectiove health and medical authority in the eightenth century. Hist Sci. 2001;39:466-499.
17. Jones WHS. The medical writings of Ananymus. Cambrige, UK: Cambridge University Press; 1947:33-40.
18. Hippocrates. Disease I. In: Paul Potter, trans. Hippocrates V. Cambridge, MA: Harvard University Press; 1988:103.
19. Bylebyl JJ. Nutrition, quantification and circulation. Bull Hist Med. 1977;1:369-385.
20. Renbourn ET. The natural history of insensible perspiration: a forgotten doctrine of health and disease. Med Hist. 1960;4(02):135-152.
21. Vegetti M. Between knowledge and practice: Hellenist medicine. In: Grmek MD, ed. Western medical thought from antiquity to middle age. Cambridge, MA: Harvard University Press; 1998:96. Original title: Storia del pensiero medico occidentale. Rome: Gius. Laterza; 1993.
22. Burnet J. Early Greek philosophy. London: A and C Black; 1908:253.
23. Harris CR. The heart and the vascular system in ancient Greek Medicine. New York: Oxford University Press; 1973.
24. Parè A. Works. Johnson T, trans. from Latin. London: Mary Clark; 1664.
25. Leonardo Botallo. Opera Omnia Medica et Chirurgica, van Horne, Ed. Gaasbeeck, ex officina Danielis et Abrahami, 1660.
26. Finberg L. The early history of the treatment for dehydration. Arch Pediatr Adolesc Med. 1998;152(1):71-73.
27. Latta T. Malignant cholera: comments contributed by the Central Board of Health, London, relative to the treatment of choler by copious injections of aqueous and saline fluids in the vein. Lancet. 1831-1832;2:274-277.
28. Quincy J. Medicina statica: being the aphorisms of Sanctorius translated into English, with large explanations.... London: T Longman and J Newton; 1728.
29. Valery P. Eupalinos o l'architetto [Eupalinos: or, The architect]. Scapolo B, ed. Udine: Mimesis; 2011:7-8.
30. Eknoyan G, De Santo NG. A brief history of human clinical research. In: De Santo NG, Eknoyan G, eds. Human clinical research: ethics and economics. Naples: Istituto Italiano per gli Studi Filosofici; 1997:56-70.
31. Altman LK. Who goes first? The story of self-experimentation in medicine. London: University Press, LTD; 1998.
32. Gourevitch D. The paths of knowledge: medicine in the Roman world. In: Grmek MD, ed. Western medical thought from antiquity to middle age. Cambridge, MA: Harvard University Press; 1998:132.

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