International Journal of Legal Medicine (2020) 134:1875–1895
https://doi.org/10.1007/s00414-020-02272-6

REVIEW

Revolution in death sciences: body farms and taphonomics blooming. A review investigating the advantages, ethical and legal aspects in a Swiss context

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Received: 26 November 2019 / Accepted: 3 March 2020 / Published online: 21 May 2020

Abstract

Taphonomy is the study of decaying organisms over time and their process of fossilization. Taphonomy, originally a branch of palaeontology and anthropology, was developed to understand the ecology of a decomposition site, how site ecology changes upon the introduction of plant or animal remains and, in turn, how site ecology affects the decomposition of these materials. In recent years, these goals were incorporated by forensic science to understand the decomposition of human cadavers, to provide a basis on which to estimate postmortem and/or postburial interval, to assist in the determination of cause and circumstances of death, and to aid in the location of clandestine graves. These goals are achieved through the study of the factors that influence cadaver decomposition (e.g. temperature, moisture, insect activity). These studies have also provided insight into the below-ground ecology of cadaver breakdown and allowed to develop useful protocols for mass disaster managements in humanitarian medicine. From the results obtained, new scientific disciplines have arisen, gathered under the word "taphonomics" such as the study of microorganisms living below/on a cadaver (thanatogeomicrobiology), and join the more classical forensic sciences such as anthropology, botany or entomology. Taking into account the specificities of the study object (human cadaver), primordial requirements are needed in terms of security (physical and environmental) as well as ethical and legal concerns which are studied in the Swiss context. The present review aims to present in a first part the concept of human forensic taphonomy facilities (HFTF, also colloquially named "body farm") leading to an enrichment of forensic sciences with new "taphonomics". The second part is focused on the mandatory points that must be addressed for a HFTF approach, especially because it requires a specific place to undertake this research which must be performed in conformity with a country's human ethics and laws.

Keywords Human taphonomy · Taphonomics · Body farms · Forensic anthropology · Swiss legal context · Swiss ethical context

Introduction

The term "taphonomy" is known to have been created by Ivan Efremov (1908-1972), a Soviet palaeontologist who defined the first concept of taphonomy, as the study of fossilization patterns [1]. The etymology is based on "taphos" meaning the grave and "nomos" meaning the laws, in order to define the mechanisms that influence the decomposition of organic material.

This concept can be defined by various scientific disciplines from biology to geology, from palaeontology to forensic sciences. Therefore, the definition and the timeframe can vary according to the goals of the taphonomic investigation and the study object (i.e. human body decomposition over several months to years in the case of forensic sciences, fossils

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diagenesis over several thousands to millions of years in the case of palaeontology).

Considering forensic taphonomy, the use of more academic disciplines such as biology, toxicology or genetics for example, has led to complete the investigation tools of forensic experts and define new disciplines such as thanatomicrobiology or thanatogeoecology (Table 1). All these scientific disciplines, investigating the human body decomposition and its surroundings, are gathered under the term "Taphonomics".

Body farms and taphonomics

Animal taphonomy

Animal taphonomy refers to taphonomic studies performed on animal body or parts of animal body excluding human being. Initially, parts of laboratory animals were used. Today, many taphonomic studies are performed on intact animal cadavers. Indeed, the extrapolation from parts of organs to the whole organism remains dubious, because of obvious biases of representativeness. Decomposition trials on a range of different animal carcasses or parts of such organisms (skeletal or muscular tissue...) have been extensively studied during the last sixty years (Table 1). Two types of approach can be differentiated: controlled taphonomic studies, mimicking actualistic studies in forensic taphonomy facilities, and uncontrolled taphonomic studies, which are also called observational studies. Uncontrolled forensic taphonomy studies gather all the forensic case reports involving decomposed cadavers which need to be examined by forensic experts in order to identify the cause and circumstances of death. Indeed, such examinations allow to precise or perform forensic diagnoses such as post-mortem interval, or the cause and circumstances of death. By studying human taphonomy, it becomes possible to confirm or infer the forensic conclusions made on a decomposed cadaver. In controlled taphonomic studies, many variables affecting the decomposition process are monitored. Table 1 compiles a list (not exhaustive) of some of those variables studied during the last century.

Larger mammals are preferred for many surface decomposition studies, due to the accelerated rate of decay in smaller analogues, because they resemble the weight or biomass of human cadavers and due to difficulties associated with identifying each stage of decomposition. Analogues are studied for various purposes (forensic, ecological, geological, etc....) through investigations of a wide range of parameters such as:

-Decomposition chemistry (intracadaveric and extracadaveric volatile organic compounds also called thanatovolatilome, intracadaveric and extracadaveric gases also called thanatogasome, biochemical compositions of cadavers...)

-Decomposition geochemistry through analyses of soils in contact with cadavers (thanatogeovolatilome, soil biochemistry...)

-Microbial activity (intracadaveric and extracadaveric microorganisms collected on and inside the cadavers also called thanatomicrobiome) [169]

-Microbial geoactivity (intracadaveric and extracadaveric microorganisms collected in soils in contact with the cadavers also called thanatogeomicrobiome) [170]

-General decomposition processes (decomposition stages, scavenging...)

-Ecology (studies of interaction between organisms and the cadavers: zoology and more specifically insect succession studies also called entomology, botany ...)

-Geoecology (studies of interaction between organisms and soils in contact with the cadavers: botany, zoology, entomology, ...)

Although animal controlled taphonomic studies carried out on organ or animal parts can be performed in the laboratory, many institutes and universities around the world have dedicated outdoor facilities to investigate intact animal taphonomy in semi-controlled environments. Such studies use animal surrogates mimicking human remains. Pigs have been extensively used for this purpose in universities in the United Kingdom, USA and Australia, and even in Switzerland at the University of Lausanne [171] and very recently at the University of Neuchâtel [42, 44]. However, there is a necessity to use human remains because animal models cannot completely mimic the human body (cardiac pathologies, diabetes, smoking habits…). In the forensic context, as the extrapolations from animal to human is still debated, it is of crucial importance to study human materials for comparative purposes [172]. Indeed, if the extrapolations from animals to human are not reliable, it appears irrelevant to conduct animal taphonomic studies to answer to forensic questions focused on human body. Moreover, there is a growing concern about the ethics conducting such studies, especially when animals are killed specifically for the study [173].

Human taphonomy

The majority of human taphonomic studies are constituted by uncontrolled taphonomic works. These works come from routine forensic case reports described by forensic experts, from medical examiners to forensic archaeologists/anthropologists, depending on the decomposition state (organic remains or skeletons). However, a very important component of the literature concerns general archaeology and palaeontology of human remains and related disciplines such as palaeogeology, palaeobotany and palaeoecology.

With respect to controlled taphonomy studies on humans, until now and for convenience reasons, most of the works have been performed only on parts of human organs sampled

Table 1 Overview of taphonomic studies according to the study models and specific aims

	Model	Decomposition chemistry (thanatovolatilome, thanatogasome)	Decomposition geochemistry (thanatogeovolatilome, soil biochemistry)	Microbial activity (thanatomicrobiome)	Microbial geoactivity (thanatogeomicrobiome)	Thanatogeoecology	Thanatoecology (entomology, botany…)	General decomposition processes (steps, scavenging…)
Vertebrate (mammals)	Guinea pigs					[3]	[3, 5]	[2, 4]
	pigs	[6, 9–24, 156, 157, 165, 168]	[18, 25–34, 120, 163, 166]		[36–38]	[28, 42–44, 118, 119]	[41, 45–66, 125, 155, 158, 160, 166]	[27, 37, 39–41, 118–120, 123, 124, 157, 158, 162, 163, 166]
	dog	[6]					[6, 7]	[35]
	sheep		[32, 67]		[68, 69]			[70, 117]
	deer		[86, 87]				[74, 87]	[88, 128]
	bison		[86, 87]				[87]	
	rabbits	[24, 80, 89, 90, 167]	[32]				[74, 77, 92–100]	[2, 91, 92, 122]
	Monkey							[101]
	Elephants						[102]	
	Goat						[77]	
	Beef	[6]	[23, 32, 87]				[88, 105]	
	Lamb	[6]	[25]					
	Moles	[24, 167]						
	Squirrels						[94]	[122]
	Opossum						[94]	
	Cat						[94, 111]	
	Cow	[22]						
	Zebra						[113]	
	Chipmunk						[74]	
	Impala						[115]	[127]
	Llama						[116]	
	rats				[71]	[129]	[73, 77, 129]	[73, 122]
	mouse	[24, 78–80, 161, 167]	[27]				[74, 81–85, 161]	[27, 122]
	Kangaroo		[32]					[114, 126]
	seals						[106]	
Vertebrate (reptiles)	turtles	[24, 167]					[103]	
	Lizards						[122]	[110]
	snake						[74]	
Vertebrate (amphibia)	Frog	[24, 81, 167]					[74]	
	Newt							[122]
	Salamander							[122]
	Toads						[110]	
Vertebrate (birds)	Birds	[24, 167]						
	Sparrow	[24, 167]					[74]	
	Finch							[122]
	Dove							[122]
	Magpie						[74]	
	Robin	[24, 80, 167]						
	Thrush	[24]						
	Woodpecker	[24]						
	Warbler	[24]						

Table 1 (continued)

	Model	Decomposition chemistry (thanatovolatilome, thanatogasome)	Decomposition geochemistry (thanatogeovolatilome, soil biochemistry)	Microbial activity (thanatomicrobiome)	Microbial geoactivity (thanatogeomicrobiome)	Thanatogeoecology	Thanatoecology (entomology, botany…)	General decomposition processes (steps, scavenging…)
	Gulls	[107]					[106]	
	Chicken / Chicks	[6, 20, 22, 83]	[32]				[112]	[35]
	duck							[108]
Vertebrate (fishes)	Trouts							[108]
	Tuna	[6]						
	salmons			[109]		[109]		
	Sturgeon	[24, 80, 167]						
Invertebrate (Molluscs)	snails						[104]	
	slugs						[104]	
Invertebrate (Annelida)	earthworms						[104]	
Arthropods (Insects)	crickets						[104, 105]	
	Human	[6, 11, 24, 130–140, 157, 167]	[132, 137, 141, 142]	[143–145]	[146, 147]	[152]	[73, 153, 154, 164]	[35, 130, 148–151, 157]

Thanatovolatilome: Study of volatile organic compounds released by dead organisms

Thanatogasome: Study of intracadaveric gases of dead organisms

Thanatomicrobiome: Study of microorganisms of dead organisms

Thanatoecology: Study of ecology of dead organisms

Thanatogeovolatilome: Study of volatile organic compounds of soil in contact with dead organisms

Thanatogeomicrobiome: Study of microorganisms of soil in contact with dead organisms

Thanatogeoecology: Study of ecology of soil in contact with dead organisms

from cadavers. An increasing number of scientific teams studying these materials is noticeable since the 2000's.

However, as with the extrapolation of results from animal models, the extrapolation from human tissues to the human cadaver is still debateable. Hence, the reason why human forensic taphonomy facility (HFTF) have been created. In HFTF, controlled actualistic taphonomic studies on human cadavers are performed and the results obtained from these studies can assist the recovery and identification of remains or forensic diagnoses. Medical examiners have to work on bodies whose taphonomy is totally unknown whereas HFTF can monitor the taphonomic variables (temperature, moisture, etc...) from the time of placement of the body. Similarities and discrepancies between those observed by medical examiners and those collected in HFTF allows forensic experts to understand the taphonomy of cadavers examined routinely in forensic centres.

The literature is well furnished with studies on uncontrolled human decomposition but the number of works concerning controlled taphonomy on human cadavers is increasing. Figure 1 shows the result of a keyword search in Pubmed using the terms "human OR cadaver OR forensic AND taphonomy" (last monitoring August 2019).

The same disciplines as those reported for controlled taphonomy on animal cadavers are also growing including: decomposition chemistry and geochemistry, microbial activity and geoactivity, general decomposition processes, ecology and geoecology, etc., all feeding into the study of "taphonomics".

Forensic human taphonomy

Police and forensic methodologies and protocols have been improved as a result of human controlled taphonomic studies. The first goal of forensic human taphonomic studies was to obtain reliable information to forensic experts for resolution of death investigations [174]. The natural phenomena of decomposition can be linked to intrinsic (analyses of the decomposing materials over time of decomposition) and extrinsic (analyses of samples/matrices in contact with decomposing materials over time of decomposition) variables as well as environmental factors (temperature, moisture, scavenging, etc.). The main objective of initial studies was to be able to confirm or refute the taphonomic hypotheses of the routine cases. However, from these first results, useful databases on bone trauma and other injuries as well as human anatomical variations have been collected too.

Deriving from this, other possibilities arose from the improvement in forensic taphonomy knowledge. Instruments and methodologies to search for human bodies and remains have permitted to strengthen geomorphological protocols through the use and development of aerial photography data treatment softwares [175, 176], and ground penetrating radar [177–179]. These techniques allow us to understand artefacts caused by scavenging [180] and to improve recovery procedures. Postmortem delay of buried or surface decomposing human bodies have been extensively investigated through the sampling and analysis of volatile organic compounds released during decay [6, 11, 24, 130–140, 141, 142]. The results from these disciplines have been directly useful for the training of canine units searching for missing persons.

On a larger scale and equally as important, the methodologies employed by police and first responder services to locate and identify missing persons and victims of homicide can be used to improve protocols for mass disaster management.

Recent global events have highlighted the need for realistic research to improve the methodologies for searching, locating, recovering, and identifying victims of natural disasters (floods, earthquakes, tsunamis, volcanic eruptions) and man-made disasters (9/11 terrorist attacks, Bali bombings, Fukushima nuclear explosion). The capability to conduct this type of research and improve search and recovery methods

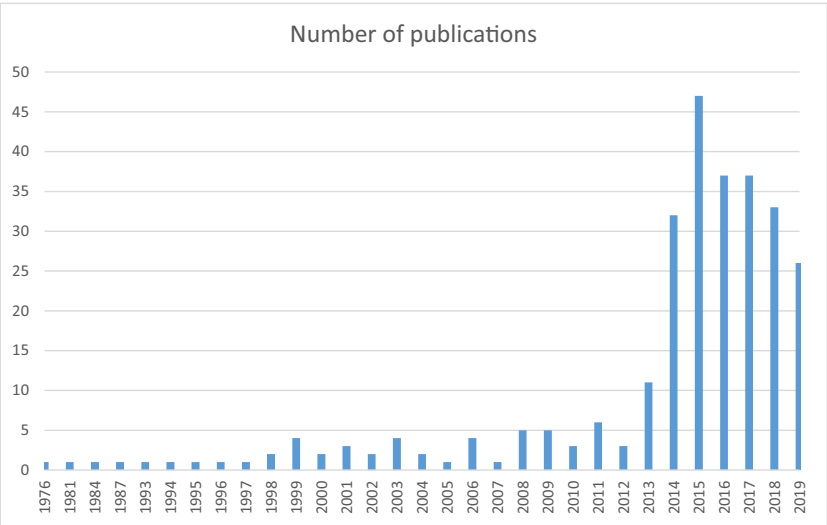

Fig. 1 Numbers of publications related to taphonomy (extracted from Pubmed on August 2019)

appears very useful. Yet the ethical use of human cadavers to conduct scientific studies is vital for the ongoing success of these investigations when providing emergency response to neighbouring / foreign countries impacted by disaster.

As a result, the forensic human taphonomy studies have encompassed the broader scope of forensic sciences but, through interdisciplinary scientific interactions, have combined forensic knowledge with technical advancements. Such improvements have brought more objective and reliable data to court, allowing forensic experts [181] to solve forensic cases, and have significantly assisted humanitarian medicine to save missing persons and to identify dead individuals during mass disasters.

Human Forensic Taphonomy Facility (HFTF)

Facilities to study of human decomposition have traditionally been established under the discipline of forensic anthropology (Table 2). The first facility established for this purpose was the Anthropology Research Facility at the University of Tennessee in Knoxville, USA. This facility was established in the early 80s by Dr William Bass and for several decades was the only facility of its kind in the world. The purpose of this facility was to provide systematic studies of human decomposition and modern human variation, pathology and trauma. These studies were carried out through a body donation program. Several overviews on HFTF are available in the literature demonstrating that they deserve a specific attention [182–184].

Over the past decade, several additional facilities have been implemented in the USA including the Forensic Osteology Research Station at Western Carolina University (2006), the Forensic Anthropology Center at Texas State University (2008), the Applied Anatomical Research Center at Sam Houston State University (2009), the Complex for Forensic Anthropology Research of Southern Illinois University at Carbondale (2012), and the Forensic Investigation Research Station at Colorado Mesa University (2013). One of the goals of these HFTF concerns elaboration of modern skeletal collections, generally unavailable, to provide criteria for sex, age, ancestry and stature estimation specific to USA population. However, such criteria for other countries are also required and HFTF development out of USA are of strong anthropological and forensic interests. Consequently, in 2016, the Australian Facility for Taphonomic Experimental Research was launched – as the first facility outside the USA. A forensic cemetery (buried bodies) also opened in 2017 in the Netherlands, managed by the Academic Medical Centre of Amsterdam. The Forensic Institute for Research, Security and Tactical Training led by the Pasco County Sheriff's Office also opened its own HFTF in Florida recently. In 2018, the Forensic Research Outdoor Station of North Michigan University was created [184]. Other projects have been planned in Wisconsin, Pennsylvania and in India, illustrating the international needs and interests for HFTF. Finally, a new facility is planned to open in 2019 in Canada, through an initiative led by the Université du Québec à Trois-Rivières These facilities also use body donation programs and provide valuable data regarding the process of human decomposition in their specific ecological environments. Unfortunately, they cannot be easily extrapolated to distinctly different environments of European countries such as and Switzerland due to

Table 2 Overview of the different body farms in activity in the world

Facility	Institution	Department	Location	Date
Anthropology Research Facility (ARF)	University of Tennessee	Anthropology	Knoxville, TN, USA	1981
Forensic Osteology Research Station (FOREST)	Western Carolina University	Anthropology	Cullowhee, NC, USA	2007
Forensic Anthropology Research Facility (FARF)	Texas State University	Anthropology	San Marcos, TX, USA	2008
Applied Anatomical Research Center of Southwest Texas (AARC)	Sam Houston State University	Criminal Justice Center	Huntsville, TX, USA	2009
Complex for Forensic Anthropology Research (CFAR)	Southern Illinois University	Anthropology	Carbondale, IL, USA	2012
Forensic Investigation Research Station (FIRS)	Colorado Mesa University	Criminal Justice	Grand Junction, CO, USA	2013
Australian Facility for Taphonomic Experimental Anthropologist Research (AFTER)	University of Technology Sydney	Centre for Forensic Sciences	Yarramundi, New South Wales, Australia	2016
Amsterdam Research Initiative for Sub-surface Taphonomy and Anthropology (ARISTA)	Amsterdam's Academic Medical Center	Medicine	Amsterdam, The Netherlands	2017
Florida Forensic Institute for Research, Security, and Tactical Training	University of Southern Florida	Anthropology	Tampa, FL, USA	2017
Forensic Research Outdoor Station (FROST)	Northern Michigan University	Anthropology	Marquette, MI, USA	2018
	University of Québec – Trois Rivières	Chemistry, Biochemistry and Physics	Québec, Canada	2019 In progress

the geographical variation in climate, geology, and ecology and the inherent impact of these factors on the process of decomposition [185].

These HFTFs constitute interdisciplinary opportunities to lead controlled studies using entire human cadavers with known post-mortem delay, observing and comparing the patterns, mechanisms and rates of decomposition between climatic, environmental and ecological areas.

However, due to the specificity of the model (human body), several safeguards have to be addressed regarding the security (physical access and environmental impacts) as well as ethical and legal conformities [186, 187]. Indeed, there is an obvious requirement to provide appropriate protective security to a HFTF: to assist in addressing the moral and ethical implications of the research, to protect the credibility and reputation of the University as well as the integrity and privacy of the donated cadavers.

Beneficiaries of the HFTF

The outcomes of the research highlighted above should benefit police services by enhancing their techniques for searching (e.g. cadaver dogs) and locating (e.g. chemical and biological markers, ground penetrating radars) human remains. The outcomes further benefit forensic services and stakeholders (forensic institutes, criminal sciences schools, continuing education and training for law enforcement authorities, Non-Governmental Organizations, etc.) by enhancing their techniques for recovering (using archaeological, anthropological, and palaeontological techniques) and identifying (e.g. bone and teeth analysis, isotopic signatures, textile and hair/fibre recovery, DNA) human remains to obtain forensically reliable data.

From an operational point of view, the research should assist estimating the time since death which can be critical to establishing an alibi and prosecuting an offender in forensic investigations through the use of forensic entomology, anthropology, and microbial succession. Circumstances and cause of death can be contextualised and may be very informative such as the ingestion of drugs or toxins or determination of human injuries from non-human/scavenging injuries. The facility should also provide a more focused collaboration between researchers, police and forensic services, ensuring that the research outcomes are directly applicable to their needs. Locating victim remains assists recovery efforts by improving search efficiency on site and reduces the amount of time and resources required. More importantly, rapid detection may lead to more rapid identification of victims and can provide some measure of comfort and resolution to the victim's family. In mass disaster and humanitarian medicine context, the research performed in HFTF addresses a strategic research priority of living in a changing environment and specifically the priority to manage risk and capture opportunities for sustainable natural and human systems. HFTF results aim to enhance police and forensic methods for managing change in the linked human and natural environment, particularly with respect to extreme events such as disasters [188].

From a multidisciplinary scientific point of view, the wholly-integrated approach to studying the decomposition process ensures that a range of multidisciplinary variables are considered in the regional environment, providing a longitudinal and replicated data set that can be analysed and interpreted by the relevant disciplines. HFTF take full advantage of the taphonomics approach to understand the human body decomposition. The data generated in HFTF represent the most comprehensive information available to police and forensic services regarding the decomposition processes of human remains in their local environment. A key benefit of researchers from different disciplines conducting multiple experiments concurrently at the facility is that the results of each can inform the others and, thereby, create novel and productive synergies across traditional disciplinary boundaries.

Improvements from studies in HFTF

A wide variety of outcomes are expected from these HFTF experiments. Each year, every HFTF produces dozens of publications proving the interests of taphonomic studies for forensic and non forensic purposes. The current work does not aim to present the very important achievements of each HFTF in all the taphonomic domains. It aims to give an overview of the very latest developments proving that the taphonomic domain is increasing and needs additional HFTF to perform these studies.

The first outcome concerns the improvement of post-mortem interval (PMI) estimation. HFTF literature is rich with studies dealing with PMI estimation on cadavers [189, 190] (Table 1). In this context, thanatomicrobiomes sampled from the cadaver or in the cadaver's surroundings are more and more investigated due to HFTF resources [191–193].

Results have already been obtained from the data generated in these facilities mainly in detection of clandestine remains due to the ecological changes (vegetation, microorganisms, etc.) caused by cadaveric fluids [170]. Technological improvements have resulted from remote sensing and geographical information system (GIS) studies to locate a decaying body. The cadaver decomposition island (CDI) formed by the decaying body can be detected by remote sensing [194], and unmanned aerial vehicles (UAV) such as (micro)drones are currently available, fully equipped with near-infrared (NIR) sensors or light detection and ranging (LiDAR) technology [176]. New multi-sensor platforms and systems are in development and can be used to assist in gravesite localization. These advancements would not have been possible without studies conducted at HFTF [195]. Other approaches for

human remains detection are based on chemical remote sensors. Many studies are focused on decomposition odour emitted from cadavers in order to develop search protocols using chemical sensors. This topic is also of importance for the training of cadaver dogs when used to locate bodies in rural areas or under the rubble after a major disaster such as an earthquake. The most advanced works have been performed at HFTF structures [11, 131, 168, 196, 197]. Following the localization step, the identification is crucial in forensic cases. To this end, studies in HFTF allow the development of new protocols to collect genetic information [198–200].

From skeletal collections, numerous improvements in biological anthropology, bioarcheology, human osteology and remains recovery have been published [184, 201, 202]. Related technologies such as imaging tools (3D-scanning and computed tomography), dating instruments (isotopic ratio mass spectrometry) and protocols have also been developed [203, 204]. Scavenging mechanisms and bone alterations are frequently investigated at HFTF and have led to improvements in search and recovery protocols [180, 205].

Some of these studies were directly linked to forensic questions and others were related to fundamental topics. However, all the works performed at HFTF are of high importance taking into account the important human problems that we face today, causing deaths all around the world. From individual to multiple forensic cases to humanitarian issues such as migrations and conflicts, human taphonomy definitely deserves more investigation.

Requirements for HFTF installation

This chapter aims to present the critical points that each HFTF in the world should consider. Therefore, requirements list concerning security and access concerns, environmental concerns and legal/moral/ethical concerns is proposed and should be followed in the case of HFTF installation project. To illustrate this last group of concerns, we have chosen to study the Swiss context, as a Western Europe example. However, because each state/country is governed by different laws, it is obvious that some discrepancies can occur regarding to already operating HFTFs.

Security and access to HFTF

When assessing the security risks, it is important to understand where the sources of threat originate from. In the context of a human physical security risk assessment, the sources of threat are always categories of people who commit various types of crimes such as trespassers, vandals, criminals, unruly people, sexual perpetrators, disgruntled staff, contractors or members of the public, people with real or perceived grievances and issue motivated groups.

To enable a comprehensive assessment of threats for the facility, it is important to assess the plausibility of an intrusion of this kind of people, and to anticipate the threats according to their potential for nuisance. It is recommended that newly established HFTF should undertake this risk assessment evaluation in order to better address the physical security [206].

Each unwanted potential intrusion should be described according to the category and aims of intrusion, the likelihood of the event and the magnitude of the consequences. This ranking allows to score the risks in category in order to define an adapted access. Several HFTF have already simplified this point by being located on land belonging to a law enforcement authority such as the Florida Forensic Institute for Research, Security and Tactical Training of the Pasco County Sheriff's Office. Other sites can have natural geographical advantages that can minimize a potential intrusion such as in Australia or in Texas (desert areas) and a canopy appears very important to prevent drones and aerial flights over HFTF.

The risk management process should demonstrate that the HFTF's risk profile is adequately managed for most foreseeable risk events. If effective security control measures are successfully implemented, then most risks can be significantly reduced to acceptable levels. As a result, the site selection for a new facility should take into account :

1. The geography and topography

According to its location, the HFTF access is naturally protected (cliffs, high declivity, desert zones, etc.) or human-protected (law enforcement authorities present on site, army, etc.). The surface of the facility should be chosen according to the possibilities to secure it.

2. Equipment

High fences and barbed wire providing intruder-resistant guarantees (i.e. anti-tamper and anti-climb), and opaque screening which prevents viewing into the facility, are commonly used. This equipment should demonstrate clearly that only authorised users are allowed on site. Internal security rules of the HFTF should be outlined in the guidelines of HFTF access.

3. Closed Circuit Television system

Cameras monitoring the perimeter fence with Day/Night capability and onsite recording, regardless of weather conditions, should be installed. This is mandatory equipment that must be installed in order to contextualise objectively any problem occurring on the HFTF site. The technology used should be able to monitor under the local weather conditions, sometimes very extreme, and be resistant to vandalism, if any.

4. Signage

Security signs spaced at regular intervals around the perimeter of the facility compound, including at the main entrance, should be installed. This shall inform people that the facility is private property, trespassers will be prosecuted, and that CCTV is in operation.

As it is rarely possible to eliminate the risks all together, HFTF management need to demonstrate that a risk evaluation has been carried out and the highest risks have received proper mitigation measures. Moreover, as some residual risks may remain, HFTF management should demonstrate that they are within tolerable levels and should perform continual monitoring on a regular basis to ensure that changes in the operational environment do not elevate these risks to unacceptable levels, and to ensure that mitigation measures remain optimal.

A similar approach has to be taken to anticipate the potential animal physical intrusion (random or attracted scavengers) for those facilities that do not allow scavenging of remains. This concern is usually resolved using wire cages whose mesh size prevents or limits the avian scavenging but still allows invertebrate scavenging. High fences sometimes equipped with anti-dig footing are often used to limit small and large animal scavenging where required.

Environmental impacts

In addition to physical security and an intrusion study, newly established HFTF may also have to plan an environmental study from a risk mitigation point of view. Indeed, the taphonomic activities can also be a source of nuisance that needs to be anticipated [207, 208]. Although decomposition studies constitute copies of natural events occurring in the environment, the human dimension of the discipline requires several points to be considered :

Archaeological and cultural heritage assessment

The site identified to host taphonomic studies should not be of archeological or cultural interest. The taphonomic area should not be listed as an archeological site because the body decomposition, due to the cadaveric fluids soil impregnation, could contaminate the archeological artefacts. Additionally, the burial of human cadavers for research purposes could disrupt and displace natural burial sites of cultural significance.

Air quality (odour) impact assessment

All organic material decay is a promoter of microbial activity. Endogenous microbial decay combined with exogenous insect activity (where applicable) results in degradation and metabolism of body macromolecules leading to elimination of smaller constituents. As the molecular size decreases, the volatility of the generated compounds increases and some of these volatile organic compounds can be highly odorant. The choice of a remote site with a reduced population decreases the odorant impact and nuisance to neighbors and reduces the risks of increased scavenging attraction.

Biological and chemical contaminants assessment

It is recommended that new HFTF attempt to control the eventual contamination of the soil and to geographically limit contamination to the perimeter of the HFTF [209]. Based on the health status of the donor (medical treatments, infectious diseases, etc.), a soil contamination through cadaveric fluid influx is possible. A preliminary basic soil analysis should be performed before the establishment of the HFTF and periodically tested to monitor ongoing contamination. It is recommended that the dimension of the HFTF site should be sufficient to avoid an environmental impact by the decomposition of human bodies, in direct proximity to the HFTF. However, most of these risks are limited by body donation rules excluding the use of infected bodies.

Flood, groundwater and geological impact assessment

The topography and geography of the HFTF site may constitute an advantage (e.g. canopy) but it may also present disadvantages. Indeed, areas subjected to floods or whose soil composition can facilitate groundwater mixing may not be ideal as HFTF sites depending on the local environment. Similarly, areas subjected to earthquakes, soil movement, or whose geological composition shows a potential risk should not be considered for taphonomic studies.

Ecological assessment for flora and fauna

Typically, the impacts of taphonomic activities will be limited to the site of the HFTF. Regardless, the site should not be listed in an area of natural protection or containing endangered species. The ecology (flora and fauna) in the vicinity of the HFTF should not be drastically changed or impacted by the taphonomic studies. It is recommended that controls and surveys be performed to monitor the state of ecologic diversity prior to construction of the facility.

Societal impacts : ethical and legal aspects of a human taphonomic model: – The Swiss context as an example

Legal human rights are in principle only applicable to living humans, and not to a cadaver. The status, treatment, and disposition of human remains is governed by national laws in each country. Collections of statutes, regulations, and judicial decisions at the state and /or federal levels as well as local ordinances are available according to the country's legal system [185, 210–212]. The use of human cadavers for practicing medical procedures, researching forensic and non forensic protocols, educating scholars and the public through exhibitions may seem to be unique in the 21st century. However, the great amount of medical, legal, and ethical questions that persist today are the products of a complex history of using human cadavers in research [213]. Until 1970's – 1980's, the ethical and legal questions from these uses were not really investigated considering the scarce applications outside anatomy medical education. The recent proliferation of taphonomic disciplines and HFTF have emphasized and proved the needs of this type of approach for social and community benefits. However, they raise simultaneously some legal and ethical issues that need to be addressed taking into account the religious, economic, demographic, social and scientific aspects of our modern world. The Swiss legal context concerning the use of the human body and/or parts of the human body is presented herein to provide some answers to the ethical challenges faced by taphonomics and HFTF.

1. Legal framework – the essentials of international law and domestic Swiss law

The use of the human body and/or parts of the human body for scientific research involves compliance with a specific legal framework in terms of international law, domestic Swiss law (in particular the Federal Act on Research involving Human Beings (the Human Research Act)) and Swiss medical-ethical guidelines.

With regard to international law, the Convention for the Protection of Human Rights and Fundamental Freedoms and the Biomedicine Convention should be mentioned [214, 215]: the first is the basis or "foundation" for the protection of fundamental rights in Europe; the second provides more detail, practical application and reinforcement of the rights in the fields of biology and medicine. The texts mandate certain principles (human dignity) and fundamental rights (right to a private life and protection of privacy) relevant to the human body and the use of parts separated from the human body and human remains. The Biomedicine Convention mandates the principle of the primacy of the human being, under which "The interests and welfare of the human being shall prevail over the sole interest of society or science" [216]. This enables the resolution of certain conflicts which may arise between human dignity and scientific developments.

With regard to domestic Swiss law, the use of a human body and/or body parts for the purpose of scientific research should comply with the following general principles:

- *Respect for the deceased and inviolability of his/her body*

Respect for the deceased and the inviolability of his/her body follow from the protection of human dignity [217–219]. They are applied in Swiss law through personal liberty (constitutional law), protection of privacy (private law) and disturbing the peace of the dead (criminal law) and are based on ethical or religious concepts relating to the significance of death.

- *Right to decide on the disposal of one's own corpse*

A corpse has a particular legal status, insofar as its fate is of interest in terms of self-awareness as well as of religious and moral convictions. Every individual therefore has the right to decide on the disposal of his/her own corpse, within the limits of law, public policy (*ordre public*) and ethical and moral standards (*bonnes mœurs*) [219–221]. This right follows from the protection of human dignity and relates to the protection of privacy and personal liberty.

- *Subsidiary right of close relatives of the deceased to dispose of the corpse*

The close relatives of a deceased person have their own right to dispose of the corpse, linked to protection of their privacy [220]. This right protects their memory of and feeling of respect for their deceased relative [219, 222, 223]. In principle, the right of the person concerned to decide on the disposal of his/her own corpse takes precedence over the right of the relatives, which applies only in the absence of provision to the contrary by the deceased [219, 221–226]. Close relatives' right to filial respect for the deceased - or right to remember - protects their emotional relationship with and personal feelings for him/her, the memory of important shared events and of specific circumstances which create attachments between individuals and which become part of their personality. Recent case law from the European Court of Human Rights in the case of *Elberte v. Latvia* (judgment of 13 January 2015) [216] illustrates this right. The applicant alleged, in particular, that the removal of tissue from her deceased husband's body had taken place without her consent or knowledge and that he had been buried with his legs tied together. This case shows that a lack of clarity in national law on the consent of close relatives to removal of tissue from the body of a deceased person and the suffering caused by such removal carried out without the knowledge or consent of the relatives can

constitute, respectively, a violation of their right to a private life, or even inhumane and degrading treatment. In this case, the Court confirmed that the suffering caused to the widow arose not only from the violation of her individual rights in relation to her closest relative and from having been left in ignorance and uncertainty as to the removal of tissue from his body but also because of the intrusive nature of the acts committed on the body of her late husband and the anguish she suffered for that reason.

- *Disturbance of the dead, violation of graves / death*

Feelings of respect for the dead and their place of burial are also protected by the criminal law, with a criminal offence of disturbing the peace of the dead [227]. It is therefore not necessary for the deceased person to have heirs for his/her body to be protected: the general feeling of respect for human remains is given the protection of the criminal law by this legislation. The case law of the Swiss Federal Court on disturbance of the peace of the dead (judgments of 12 March 2003 [227] and 25 January 2010 [228]) shows that breaches of the rules of the profession – even by omission – can constitute desecration. Examples of disturbance to the peace of dead are for example asking a person without specific training to remove a cardiac stimulator from the body of a deceased person, or failing to properly wash and dress the blood-covered corpse of an accident victim.

Furthermore, under Swiss law, the use of human bodies or body parts for the purposes of scientific research falls within the scope of the Federal Act on Research involving Human Beings (HRA) and the ordonnances relating to it [229].

Finally, as in most countries all over the world, the use of a human body and/or human body parts for the purposes of scientific research in Switzerland involves compliance with certain medical-ethical guidelines. The use of a corpse or parts of a corpse in medical research and education at undergraduate and post-graduate levels and in continuing education is the subject of specific guidelines issued by the Swiss Academy of Medical Sciences. However, relevant federal and cantonal law take precedence over these guidelines, to the extent that they have no legal force. Depending on the circumstances, the guidelines may, however, be mandatory to the extent that they express best medical practice and/or are relevant in terms of applicable ethical requirements. Forensic research on the body of a deceased person falls at first sight into the scope of the HRA. In addition under the provisions of the Act, any research project on a deceased person must in the first place be submitted for approval by a competent ethics committee. Approval is given if the ethical, legal and scientific requirements specified in the Act are fulfilled, in particular in relation to scientific relevance and consent. From an ethical perspective, the extent to which the corpse is damaged as a result of the research is an issue to be taken into consideration in the assessment. Finally, as a general point, research can be undertaken on the body of a deceased person if that person, while still alive, consented to the fact that his/her body is used for research purposes. In the absence of a document confirming the consent or the refusal of the deceased person, the body or body parts may be used for research purposes with the consent of close relatives or of a trusted person appointed by the deceased person before his/her death. Consent given by close relatives or by the trusted person is governed by the Federal Act on the Transplantation of Organs, Tissues and Cells [230].

2. Compliance with fundamental rights

The recent case law of the European Court of Human Rights in the *Elberte v Latvia* case illustrates how the lack of clarity in national law on the consent of close relatives to removal of tissue from the body of a deceased person and the suffering caused by such removal carried out without the knowledge or consent of the relatives can constitute a violation of their right to a private life, or even inhumane and degrading treatment. It is therefore appropriate to consider how the legal regime specifically applicable to the use of human bodies and body parts complies with fundamental rights.

The Swiss Federal Constitution includes a provision specifically covering research on human beings (Article 118*b*) which makes the requirement for informed consent one of the principles to be followed in this area, including for research on deceased persons [231]. As a specific rule compared to other relevant principles and fundamental rights (human dignity, personal liberty, right to a private life, freedom of religion and freedom of science), this provision takes precedence over the other principles and fundamental rights, particularly as it is intended to give practical application to a framework of protection which integrates the other principles and fundamental rights. The framework of protection provided by this specific rule and the HRA which brings it into effect, and which includes in particular rules on informed consent, drawn up by reference the Federal Act on organ transplantation appears at first sight to be compatible with the fundamental rights laid down in the Federal Constitution.

An examination of the principles and fundamental rights provided in particular by the European Court of Human Rights (ECHR) and the Biomedicine Convention indicates that they are applicable to research on deceased persons and that the guarantees in international law are not at first sight more extensive than those provided by the Federal Constitution. It follows that, to the extent that the specific rule provided by the Federal Constitution (Article 118*b*) is compatible with the principles and fundamental rights laid down in the Federal Constitution, the specific rule and the HRA which brings it into effect appear at first sight to be similarly compatible with the guarantees and restrictions laid down in

international law and in particular with the principle of the primacy of the human being and the requirement for an informed consent regime which is sufficiently clear.

3. Compliance with public policy

Having considered the compliance with fundamental rights of the regulatory regime specifically applicable to the use of human corpses and parts of corpses in research, it is appropriate to consider whether and to what extent such use appears compatible with the public policy rules which follow from the specific frameworks.

- *No problem of principle*

In relation to scientific research on deceased persons, the public policy rules essentially comprise the HRA, which refers to the Federal Act on Organ Transplantation in relation to consent. Generally, and from a strictly legal standpoint, the use of human corpses and parts of corpses for the purposes of scientific research does not appear at first sight to raise any problem of principle from the perspective of public policy, and more precisely the specific legal rules which must be applied to scientific research and teaching.

- *Reservations in respect of legal and ethical requirements applicable in each individual case*

However, in the absence of a problem of principle, there is a need for reservations in relation to the legal and ethical requirements applicable in each individual case, particularly, where relevant, the decisions of the ethics committee with competence to approve protocols for proposed research projects. In addition, reservations are also appropriate for public policy in relation to environmental law, planning and building, protection of soils, (organic) waste (chemical) pollution, protection of forests and waterways and, as necessary, local public policy related to the policy benefits represented by safety, health, hygiene, peace and quiet, and public morals. These will be the subject of an additional opinion as, it should be noted, the evaluation presented herein focuses on the specific questions raised by public policy on research and education in relation to the applicable federal and cantonal law, which specifically regulates several of these policy benefits.

4. Compliance with ethical and moral standards

The use of corpses and parts of corpses for the purposes of research does not at first sight appear to give rise to any problem of principle in relation to public policy on research, subject to the legal and ethical requirements applicable to each individual case. However, the question arises as to whether the same applies to ethical and moral standards, i.e. the social acceptability of the type of research and education proposed. Indeed, ethical and moral standards are often swept up with public policy, but do not always amount to the same thing.

In an area as sensitive as the use of human corpses and body parts for the purposes of scientific and educational practices developments hitherto unknown in Switzerland, considerations of morality or relating to the social acceptability of the new practices should be taken seriously and explored. Indeed, this type of research is largely unknown to the public and likely to touch on ethical and religious concepts relating to the meaning of death and the treatment of human remains. However, at first sight, such considerations could not, of themselves, justify the prohibition of the new research or educational practices.

In this respect, there appears to be every sign that "donating your body to science" and, consequently, the use of corpses and parts of corpses in research and education are currently quite widely accepted in Swiss society. In other words, there appears to be quite a wide social consensus in favour of these practices, even though it is difficult to measure the extent to which the practices are truly accepted and rooted in the cultures and concepts prevalent in Swiss society, particularly in view of their potentially heterogeneous nature.

It may be helpful to note that, for establishing the content of ethical and moral standards, evidence from opinion polls has very limited value, as a result of issues such as the number and type of questions asked, the methods of interpreting the results obtained and the size and representativeness of the population sample surveyed.

That being noted, the perception of a consensus and social acceptance reflects the fact that the international, national and local media regularly cover certain activities of and interventions by forensic medicine, particularly in relation to the identification of victims of natural catastrophes or murders, and discovery of the causes of death in suspicious or criminal circumstances in legal cases which can sometimes attract high levels of attention. In addition, a number of documentaries and television series have certainly helped to raise awareness of, if not popularise, certain aspects of forensic medicine.

The combined effects of journalism and fiction have in this way certainly convinced a very large number of people in a general way of the public interest of forensic medicine and its essential contribution to the public good, in particular in terms of public safety, and consequently of the social utility or even the essential nature of research and education in this field, at least when the research activities take place in premises designed for the purpose.

However, even if forensic medicine generally has a "good press" and the value of its activity to society and as a consequence the need for the research and education essential to its development are now well established. Nevertheless, it is not certain that this support in principle is necessarily applicable in all circumstances and for all types of research and

education, in particular when the activity relates to the study of the decomposition of corpses or parts of corpses in the open air. Indeed, generally, certain research activities which may involve very significant interventions on corpses appear to be well accepted by society when they are carried out in closed premises designed for the purpose. However, it is not at first sight possible to infer from this that the study of the decomposition of corpses or parts of corpses in the open air benefits from the same social acceptance or support, having regard in particular to impact of proximity. In consequence, even for activities which may otherwise be compliant with the requirements of mandatory legislation on research and education and in particular which have research protocols authorised by ethics committee and programs of teaching approved by the academic authorities, the possibility cannot be excluded that the impact of the proximity of the project or even the nature, purpose and specific features of proposed uses could give rise to opposition in areas close to the site, in particular in the communities which are its immediate neighbours, and also among the general public, or at least certain sections of it, and some circles. The reasons would be based on adverse impact on other policy benefits: safety, health, hygiene, peace and quiet, and public morals, in particular during any proceedings relating to construction permits and also in the media and with the relevant political authorities. That is why it is essential to accompany the definition, organisation and implementation of such projects with a communication policy, strategy and tools helping to ensure that the general public and interested groups are well informed and in particular promoting understanding of the issues and the scientific importance of such projects and their social and political acceptability.

5. General recommendations for Switzerland

Under the general principles that we have set out, every individual has the right to decide on the disposal of his/her own corpse, within the limits of law, public policy and ethical and moral standards. The reference to ethical and moral standards and public policy constitutes an insertion of ethics, morality and public policy into law and that it thus requires that the values and principles which underpin the law should be taken into account in its application. We have also seen that, in the absence of a decision by the deceased, his/her close relatives may, within certain limits, decide on the treatment of the corpse. In other words, they have their own right to dispose of the corpse which is subsidiary to the right of the deceased. In the fields of the use of corpses or parts of corpses in research, the general principles summarised above are the subject of specific regulatory regimes respectively provided by the HRA. Through the reference to the Federal Act on the Transplantation of Organs, Tissues and Cells, the regulatory regime and requirements relating to consent are essentially the same in relation to research. In substance, a corpse or parts of a corpse may be used in research if the person concerned, consented to the use while alive. In the absence of a document confirming the consent or the refusal of the deceased person, the body or body parts may be used for research purposes with the consent of close relatives or of a trusted person appointed by the deceased person before his/her death.

- Exclusivity of the right of the person concerned and exclusion of the right of close relatives

Even though the relevant regulatory regime reserves in principle and generally the subsidiary rights of close relatives or a trusted person appointed by the deceased person before his/her death to authorise the use of the corpse or parts of the corpse in research and education, in view of the novelty and sensitivity of the use of corpses or parts of corpses in research and education, it appears appropriate from an ethical perspective, at least initially, to exclude the subsidiary right of close relatives or a trusted person to authorise such uses. In other words, to permit the use of a corpse or parts of a corpse for research purposes only if the individual himself or herself has, while alive, given written consent to such use, on the basis of specific information and a consent form including options allowing the expression of differentiated choices, and giving the person concerned the opportunity to take account of possible objections from close relatives or a trusted person.

- Information sheet for donors

The information sheet should include general information about the nature, goals, duration and approach of the use of corpses and parts of corpses in research and education in general and the treatment of or what will happen to the remains when use is completed, in particular, where appropriate, the options available to the person concerned in terms of cremation or burial. More specific information may be present, if needed, in this information sheet according to the projects.

- Consent form for donors

The consent form which accompanies the information sheet and covers the different uses described should include a set of options offering the person concerned the opportunity to make differentiated choices (alternative or cumulative) by means of boxes to tick enabling him/her first to express the will to agree, in a general manner, to the use of his/her body or body parts for scientific purposes. Secondly, the consent form allows to express the will to agree to the use of his/her body or body parts in the context of a specific research project.

- Taking account of the wishes of close relatives or a trusted person

Again in view of the novelty and sensitivity of the proposed uses of corpses or parts of corpses for purposes of research and education, and for ethical reasons, even though the right of the person concerned has precedence in principle over the right of close relatives, in the event that the person concerned expresses their explicit will to specifically accept the use of his/her body or body parts for scientific purposes by ticking the relevant box, it would be appropriate to give him/her the opportunity, independently of his/her own choice and if he/she so wishes, to allow close relatives and/or a trusted person to express their wishes and, if appropriate, to express their objection to the specific use in question. The person concerned should be invited to provide the names of the close relatives or trusted person to be contacted for this purpose, with the objection of one of them taking precedence over the will of the person concerned.

Conclusion

The importance of research involving human decomposition cannot be understated, especially following recent global events that have highlighted the need to improve our techniques for search and recovery of victims. Improvement in the training and application of these techniques can considerably enhance the success of victim recovery teams and lessen the impact on families and the community following homicides, mass disasters and other unnatural deaths.

Research involving human decomposition is more and more carried out in Human Forensic Taphonomic Facilities where taphonomics can be studied and useful information obtained concerning the cause and circumstances of death. Decomposition is inherently impacted by the surrounding environment, particularly by environmental conditions such as temperature, rainfall, humidity, air current and solar radiation. Factors specific to the geological formation (such as soil texture, pH, moisture content and electrical conductivity) as well as the ecological community (such as vertebrate and invertebrate scavengers and microorganisms) also play a major role in decomposition processes. All these parameters are studied through respective taphonomical topics and must be controlled to better understand the observations performed in routine cases to provide a real added value to forensic stakeholders needs.

However, even with the proliferation of new HTFT, these structures need to respect a security frame which must provide guarantees in terms of physical and environmental security as well as ethical and legal conformities. The Swiss example shows an overview of the legal mandatory prerequisites that should be observed in such a case.

Author contribution Review conception was initiated and conceptualised by Vincent VARLET. All the ethical and legal aspects have been written by Charles JOYE. The first draft was written by Vincent VARLET and Charles JOYE, later improved by Shari FORBES and Silke GRABHERR and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest and received no specific funding for this review.

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