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Explanatory Notes

The IT'IS database aims to provide the most complete, accurate, and up-to-date collection of tissue properties currently available in the literature. At present, the database contains data on the following tissue properties:

- Density
- Thermal Parameters
  - Specific Heat Capacity HC
  - Thermal Conductivity TC
  - Heat Transfer Rate (Blood Perfusion) HTR
  - Heat Generation Rate HGR
- Dielectric Properties
  - Conductivity
  - Permittivity
  - Low Frequency Conductivity LFC
- Acoustic Properties
  - Speed of Sound SoS
  - Non-Linearity Parameter NLP
  - Attenuation Constant ACO
- Relaxation Times at 1.5 and 3.0 Tesla
  - Longitudinal Relaxation Times T_1 T_1
  - Transverse Relaxation Times T_2 T_2
- Fluid Properties
  - Dynamic Viscosity DV
- Elemental Composition EC

Average values and other statistical information (numbers of literature values, standard deviations, minima and maxima) are provided. Variations in reported values can be caused by multiple factors. Care is taken to reject any literature value with questionable accuracy that could lower the validity of the data base value.

General Considerations

The systematic literature search started in 2011 and is currently ongoing. The database is periodically updated with new parameters, and the averages of existing parameters refreshed when new values appear in the literature. All previous versions are archived and remain available at the downloads page. A log file that summarizes all changes and additions to the database is included in the download of the database.
For inclusion, data collected from *in vivo* experiments in healthy humans are preferred. Certain experimental instrumentation and protocols, i.e., highly invasive *in vivo* studies or excision of sample tissues, are not feasible in human test subjects, in which case, animal data are preferred. The conditions used to obtain measurements from experiments conducted on excised tissues should resemble physiological conditions as closely as possible. Values derived from experiments performed on tissues that have been preserved for extensive periods of time or excised from deceased individuals should be avoided, unless no other data is available and no substitute is deemed meaningful.

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Data obtained from animal tissues of similar size and physiology, such as primates, pigs sheep and cows are preferred.
. We further generally avoid the inclusion of rodent data or data from poikilothermic animals.

Tissue Substitutions
Provision of material parameters for all tissues of the 'Virtual Population', regional human, and animal models is a high priority. Since literature data is not available for all tissues and parameters, missing data is substituted with data from tissues having similar histology, physiology, and function. In a few cases, when data from a single tissue would be inadequate, a tissue value can be substituted with a value calculated as the average from two tissues.
This is the case for the thymus, where lymph node and fat are used for its properties
[1]. The properties of tissues for which no suitable substitute tissue is available may remain inaccessible. Extracellular fluid is an exception, where the tissue properties are collected from various different bodily fluids (interstitial, pericardial, pleural and synovial fluid) as one fluid could not provide the necessary literature by itself for each property.
Density and Thermal Parameters
Supplementary to the density values in the material database, temperature-dependent densities for air can be found in the fluid properties database.

Specific Heat Capacity (HC) and Thermal Conductivity (TC)
Additional temperature dependent HC and TC for air can be found in the fluid properties database.

Blood Perfusion Heat Transfer Rate (HTR)
Determination of the HTR is challenging not only because of large inter/intraspecific differences but also due to the many internal and external factors that can temporally increase or decrease blood flow to tissues. Whenever possible, only data obtained from experimental measurements performed on healthy human subjects is collected, whereby subjects are at rest (or anesthetized) and lying supine, as different body positions can influence tissue perfusion. Animals are usually anesthetized. The values published by Williams and Leggett 1989 [2] are reported as a percentage of total cardiac output (%CO), which is considered to be 6700 ml/min for men and 5800 ml/min for women. In cases where gender identity was not included, the cardiac output was taken as the average of both genders.

Heat Generation Rate (HGR)
The heat generated by a tissue results from its metabolic activity, thus HGR is correlated with the HTR of the tissue and is calculated from the HTR based on the formula by Gordon et al. 1976 [3]**.**

Dielectric Parameters
Dielectric properties covering a broad spectrum from few Hz to several GHz are presented as a 4 Cole-Cole dispersion model. Most of the data is derived from Gabriel et al., 1996 [4]**.**

Low-Frequency Conductivity
The broad frequency dispersion model of the dielectric properties can be used to solve for conductivities at low frequencies, although the values determined at less than 1 MHz are less accurate, as stated in [4]. Therefore, an alternative database is provided, solely considering values measured at frequencies from 1 Hz to 1 MHz. The literature data is included according to the criteria listed in the "General Considerations" section. The literature on low frequency conductivity is scattered across the frequency and intra specimen variability remains high. For these reasons, it is difficult to provide values by frequency and the data is provided as average, standard deviation, minima, and maxima for each tissue.
The included data is measured using different methods, such as direct applied current (DAC), electrical impedance tomography (EIT), magnetic resonance electrical impedance tomography (MREIT), as well as diffusion tensor imaging (DTI). The diffusion tensor eigenvalues reflect the free

movement of water molecules within the tissue which can be correlated with the low frequency conductivity of tissues according to the formula in Tuch et al., 2001 [5]. Alternatively, some authors choose to rely on their own correlation.

Starting with v4.1 the low frequency database uses Cochrane's formula to combine standard deviation values from provided by the literature [6]. The standard deviation for other tissue parameters in the database will be updated in a future release, and currently is computed as the average standard deviation.

The combined standard deviation is computed using following formulae:

$$t_x = \sum_g \mu_g n_g$$

$$t_{xx} = \sum_g \sigma^2 (n_g - 1) + \frac{(\mu_g n_g)^2}{n_g}$$

$$t_n = \sum_g n_g$$

$$\sigma_{combined} = \sqrt{\frac{t_{xx} - \frac{t_x^2}{t_n}}{t_n - 1}}$$

Fluid parameters

The dynamic viscosity of several biological fluids is reported at 37°C and, when possible, at various other temperatures. Viscosity data for air and water over a wide temperature range are available, which allows calculation of the temperature-dependent fit, which is used to approximate the viscosity of these fluids at 37°C.

Acoustic parameters

Data is provided for the following acoustic properties: speed of sound, attenuation, and non-linearity (B/A). Due to the scarcity of the available information, no distinction is made between attenuation and absorption. For attenuation, a frequency dependence of the form $\alpha=\alpha_0 * f^b$ is assumed, where α (Np/m) is the absorption coefficient for a given frequency f, $\alpha 0$ (Np/m/Hz) is a medium constant, and b is also a numerical constant dependent on the tissue type [7]. For the attenuation relationship, the parameters α and b were obtained by fitting the available data. Whenever a source provides a frequency dependence over a given frequency range, that function was sampled throughout the interval, with a ratio of 1.2 to the previous frequency to provide data points for the fit. Cortical bone shows anisotropic attenuation along the longitudinal vs. parallel and radial direction. The reported values were fitted along all three directions. For missing data on speed of sound in soft tissues, an arbitrary value of 1500 m/s is used a placeholder until a proper value is found in the literature. To make those cases clearly identifiable n is set to (0). Data on B/A remain sparse and are reported only for a fraction of the tissues in the database.

Longitudinal and transversal relaxation times (T1/T2)

Values are extracted from various publications found in different databases. The longitudinal and transverse relaxation times are reported at 1.5 and 3.0 Tesla. The values in the database originate from *in vivo* studies in healthy adult humans. For blood, both human and bovine studies are included since the blood composition of bovines is comparable to that of humans. Studies with pathological hematocrit and oxygen saturation are excluded. For those tissues for which no values can be found, either we assume that the relaxation times are the same as those of tissues of similar composition, or no value is provided.

Elemental Composition

A separate Excel file is available, providing the contribution of each element to the available tissues as fraction.

References

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