

CardiaNova reference research

Summary of the source(nont) folder: BiVACOR reference data, the human side of two device designs, and how each number was checked

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Faculty of Medicine, Chiang Mai University. CardiaNova total artificial heart project. Reference research owner: Non.
Compiled from work dated 10 September 2026, this summary dated 10 September 2026.

Nothing in this document is a CardiaNova result. It is external reference data about other teams' devices and about the human recipient, gathered so that CardiaNova geometry and reliability inputs can be compared against something built and implanted. No hardware was tested. No figure here supports a clinical or regulatory statement.

1. What the folder holds

File	Contents	Lines
BIVACOR-REFERENCE.md	Sourced dimensions and operating data for the BiVACOR rotary total artificial heart, plus LVAD and pulsatile TAH comparison rows. Every value keyed to a paper, patent, regulatory document, engineers' article or press release.	396
BIVACOR-RESEARCH-REPORT.md	Audit trail for the file above: method, what failed, fact by fact provenance, corrections.	314
BIVACOR.md	The two files above concatenated. Regenerated after every fix so it cannot drift.	714
HEART-DESIGN-DATA.md	The average man (ICRP reference male and Thai data), pressures and vessel diameters at the four connections, LVAD and TAH connection hardware, collected design constraints.	567
HEART-DESIGN-DATA-RESEARCH-REPORT.md	Audit trail: three passes, failures with retry cost, provenance table.	225
note11221.md	Non's original brief: two device models at real scale for an average man, with pressure and connectivity. The data part is done; the 3D part was deliberately not attempted.	17
report/1.md to 18.md	Run logs written under Ton's reporting rule. 17 is the accuracy check, 18 the fixes.	

How to read a source key

Tag	Meaning	Weight
[PAPER]	Peer reviewed article or reviewed conference paper	Highest
[GUIDE]	Clinical guideline or consensus statement from a named body	High for a definition or threshold
[REG]	FDA public document under a PMA number	High, device specific, dated
[PATENT]	Granted patent, BiVACOR Inc as assignee	Authoritative as disclosure; states claimed ranges, not one built part
[ICRP]	ICRP Publication 89 reference values	High for the reference man; population is Western

Tag	Meaning	Weight
[REF] [TEXT]	StatPearls chapter with named authors and date; open textbook	Good for textbook normal ranges
[TEAM-MAG] [PRESS] [MFR]	Engineers' magazine article; joint press release; manufacturer site	Round numbers, a date or a place; marketing register
[DERIVED]	Arithmetic done in the file on two or more sourced figures, shown in full	Not a measurement

2. BiVACOR, the rotary total artificial heart

One motor, one moving part: a magnetically levitated dual sided rotor with left vanes on one face and right vanes on the other, in a single cavity split into a left and a right pump chamber. No valves, no diaphragms, no mechanical bearings. Left and right output are balanced by shifting the rotor axially, which changes the relative efficiency of the two vane sets. First in human implant on 9 July 2024 at Baylor St Luke's Medical Center, Houston, with 8 days of support before transplant [PAPER-1][PAPER-4][PAPER-8][PRESS-1].

Whole device

Parameter	Value	Source
Outer diameter and height	approx 60 mm and approx 70 mm	[PAPER-1] Kurita 2014, ISMB14
Mass	approx 650 g, slightly heavier than an adult human heart	[TEAM-MAG-1] IEEE Spectrum 2019
Housing	Titanium	[TEAM-MAG-1][MFR-1]
Patient size limit	Body surface area over 1.4 m² (manufacturer claim)	[MFR-1]
External hardware	approx 4 kg controller pack, two batteries at about 5 h each	[TEAM-MAG-1]
Working clearance	at least 240 µm in normal operation, 100 µm under extremes; over 20 red blood cells	[PAPER-4][TEAM-MAG-1], two independent sources
Axial gaps, patent	250 to 350 µm, typically 300 µm	[PATENT-1][PATENT-2]
Motor air gap	3.4 mm, described as very wide	[PAPER-1]

Rotor geometry from the patents, working value and claimed bracket

Both patents (US 10,543,301 B2 and US 11,833,341 B2, inventor Daniel Timms, assignee BiVACOR Inc, priority 6 January 2016) carry the same bracket lists. Treat the 'approximately' value as the design intent and the bracket as legal scope, not as a tolerance.

Parameter	Left side	Right side
Outer vane diameter	approx 50 mm (45 to 55, or 48 to 52)	approx 24 to 25 mm (22 to 27)
Primary vane inner diameter	approx 25 to 30 mm (25 to 35)	16 mm (14 to 18)
Secondary vane inner diameter	approx 35 mm (30 to 40)	approx 19 mm (18 to 20)
Vane height	approx 2 mm (1.5 to 3)	approx 17.5 mm (15 to 20)
Vane inlet and outlet angle	approx 84 and 40 deg	approx 90 and 90 deg
Volute base circle and outer wall	approx 60 mm and approx 71 mm (65 to 76)	outlet width 8 to 12 mm
Outlet throat area	approx 140 to 150 mm²	approx 150 to 200 mm²
Cutwater angle	approx 45 deg	approx 70 deg
Minimum vane passage area	150 mm²	650 mm²
Pressure rise at 6 L/min	approx 80 mmHg (60 to 100)	approx 20 mmHg (10 to 30)
200 µm axial shift changes	flow by at least 2 L/min or head by at least 40 mmHg	flow by 0.5 to 1.5 L/min or head by at least 10 mmHg
Rotor, cavity, inlet, radial gap	rotor height approx 10 mm; cavity approx 28 mm; inlet approx 18 to 20 mm; rotor to wall approx 4 mm average	

The 2 mm left vane against the 17.5 mm right vane is the whole trick: the same speed must give roughly 80 mmHg on the left and roughly 20 mmHg on the right, and the vane geometry, not the speed, carries that difference.

Suspension, motor and operating envelope

Item	Value	Source
Axial suspension	three horseshoe electromagnets 120 deg apart, two ring permanent magnets on the rotor for bias flux, three eddy current displacement sensors	[PAPER-1]
Radial support	passive hydrodynamic	[PAPER-2]
Motor	axial flux brushless DC, twelve stator poles, eight rotor magnets, back EMF for position; virtual zero power control near 0.1 A	[PAPER-1]
Axial rotor travel	± 0.3 mm in position control; ± 0.15 mm and under 15.5 W in the 2010 development bearing	[PAPER-1][PAPER-2]
Speed	1800 to 2800 rpm levitated in the chronic animal trial; 1600 to 2700 rpm per the engineers; 2400 ± 100 rpm bench point; 1000 to 1250 rpm at implantation then approx 1800	[PAPER-1][TEAM-MAG-1][PAPER-4][PATENT-1]
Flow	2 to 8 L/min, up to 12 L/min in exercise; over 12 L/min per side claimed	[PATENT-1][TEAM-MAG-1][MFR-1]
Bench hemocompatibility point	5.0 ± 0.2 L/min, left 100 ± 4 mmHg, right 27 ± 4 mmHg; loop volume 0.42 L (loop, not device prime)	[PAPER-4]
Pulsatile mode	speed modulation to 1200 rpm giving 40 to 80 mmHg pulse pressure; washout pulse 700 rpm once per minute; or plus 900 rpm at 1 Hz	[PAPER-4][PAPER-5]
Hemolysis, normalised index	0.004 ± 0.003 g/100 L continuous and pulsatile, against 0.003 ± 0.002 for the CentriMag reference	[PAPER-4]
Anatomical fit, 10 transplant patients	spine to sternum at T10 mean 14 cm (11 to 18); aorta to aortic port 0.2 cm (0 to 0.5); PA to PA port 4.2 cm (1 to 7); fitted all ten; mean age 53, mean BMI 28	[PAPER-6]

Comparison devices

Device	Envelope, mass	Displacement or stroke	Speed and flow	Source
HeartMate 3 (LVAD)	69 mm dia x 30 mm high; 200 g including cannula, graft and hardware	50 cc prime	2000 to 5500 rpm; up to 10 L/min clinically, one review says 13	[PAPER-9][PAPER-11]
HeartWare HVAD	50 mm dia; 145 g	50 cc	2400 to 3200 rpm; up to 10 L/min	[PAPER-9]
HeartMate II	40 mm dia x 60 mm long	63 mL	3 to 10 L/min	[PAPER-9]
SynCardia CardioWest TAH-t	not given in the FDA documents	70 mL max per ventricle, set to 50 to 65 mL; valves 27 mm in, 25 mm out	up to 9.5 L/min; 110 to 130 bpm; drive 180 to 220 and 50 to 70 mmHg	[REG-1]
CARMAT Aeson	external system about 4 kg	60 mL ventricle, stroke 55 to 60 mL, four biological valves	2 to 9 L/min; 35 to 150 bpm	[PAPER-7]

Not published for BiVACOR, do not fill in from memory: rotor mass and inertia, bare pump displacement volume, wall thickness and titanium grade, as-implanted cuff and graft dimensions, current motor and system power, any qualified reliability or survival figure.

3. The human side: average man, pressures, vessels

The average man

Quantity	ICRP reference adult male [ICRP-1]	Thai adult men, what is published
Height	176 cm	169.2 cm, 21 year old recruits, 2006 series (164.4 cm in 1972) [PAPER-T1]
Body mass	73 kg	no survey mean retrieved; [DERIVED] 66.7 kg from 169.2 cm and BMI 23.3, or 64.4 kg with BMI 22.5
Body mass index		23.3 kg/m ² men 20 to 59, NHES 2009 (21.6 in 1991) [PAPER-T2]; conscripts 21.7 (2009) to 22.5 (2024) [PAPER-T3]
Body surface area	1.90 m ²	[DERIVED] 1.77 m ² by Mosteller on 169.2 cm and 66.7 kg [PAPER-M1]
Blood volume, heart mass	5300 ml; heart 330 g tissue, 840 g with blood	
Cardiac output at rest	6.5 L/min (female 5.9); [DERIVED] cardiac index 3.4 L/min per m ²	

ICRP states its reference values rest on Western European and North American data. A Thai man is plausibly about 7 cm shorter and 6 to 9 kg lighter, with a body surface area nearer 1.77 than 1.90 m². The Thai weight is derived, not measured, and needs a real survey figure before it is used for anything. The ICRP values could not be re-fetched in the accuracy check (publisher returns 403); they stand as first read.

Pressure at the four connections, healthy adult at rest

Site	Value	Source
Aorta	normal under 120 and under 80 mmHg; prehypertension 120 to 139 or 80 to 89; typical 120/80, MAP about 93, normal MAP 70 to 110, below 60 sustained is inadequate	[GUIDE-1] JNC 7; [TEXT-1] OpenStax
Pulmonary artery	mean 14.0 ± 3.3 mmHg at rest (n 1187, 47 catheter studies, 13 countries), rarely over 20; mild exercise 19.4 ± 4.8 under 50 yrs, 29.4 ± 8.4 at 50 and over; systolic 15 to 30, diastolic 4 to 12; PH defined as mean over 20	[PAPER-P1] Kovacs 2009; [GUIDE-2] Simonneau 2019; [REF-1]
Left atrium and pulmonary veins, via wedge	4 to 12 mmHg; review gives 5 to 12; 15 and below in the pre-capillary PH definition	[REF-1][REF-2][PAPER-P3][GUIDE-2]
Right atrium and venae cavae	mean RA 1 to 5 mmHg, usually under 5; CVP 0 to 10 supine breathing spontaneously; RV 15 to 30 over 1 to 7	[REF-1][REF-2][PAPER-P3]
Pressure rise implied [DERIVED]	left 58 to 106 mmHg (BiVACOR bench 100 ± 4; params.py 100); right 9 to 19 mmHg (BiVACOR bench 27 ± 4, above the physiological range; params.py 15)	section 3.6 of the data file

Vessel diameters at the four connections, internal lumen, adults

Vessel	Value	Cohort	Source
Ascending aorta, men	34.1 ± 3.9 mm, range 23.1 to 49.6, at the right pulmonary artery level	1767 men, Framingham, mean age 49.8	[PAPER-A1] Rogers 2013
Main pulmonary artery	25.1 ± 2.8 mm; upper normal 29 mm men, 27 mm women (90th percentile)	3171, 51% men, mean age 51	[PAPER-A2] Truong 2012
Pulmonary vein ostia	right superior 17.6, right inferior 17.1, left superior 16.6, left inferior 14.8 mm; middle lobe vein 8.6; 82% have four veins	200, 162 men, age 24 to 79	[PAPER-A3] Cronin 2007, means only; two printed CIs are faulty
Superior vena cava, maximum in cycle	19.48 ± 2.57 mm upper level; 17.43 ± 3.09 mm at the right atrium	152, no right heart disease	[PAPER-A4] Deng 2021

Vessel	Value	Cohort	Source
Inferior vena cava, 2 cm from the right atrium	16.9 ± 3.2 mm anteroposterior by 26.2 ± 3.6 mm transverse; it is not round	200 Indian adults, 19 to 83	[PAPER-A5] Ansari 2022
Typical, textbook	aorta 2.0 to 3.2 cm; venae cavae 2.0 cm	ICRP tabulation of Brobeck 1979	[ICRP-1] Table 7.1

No Thai or Southeast Asian vessel reference study was found. All cohorts above are Western, Indian or mixed.

4. Two devices at real scale: where they connect

The brief lists the vena cava, aorta, pulmonary vein and pulmonary artery as connections. Implanted devices do not connect that way, and the data file says so with sources.

	Left ventricular assist device	Total artificial heart
Connections	Two. Inflow at the left ventricular apex anterior wall, about 2 cm lateral to the left anterior descending artery; outflow to the ascending aorta on the right curvature about 2 cm above the sinotubular junction [PAPER-L1]. It never touches the venae cavae, pulmonary veins or pulmonary artery.	Four: right atrium, pulmonary artery, left atrium, aorta, placed after the native ventricles are excised [REG-1]. The venae cavae and pulmonary veins stay on their atria; the device meets them through the atrial remnant.
Hardware, reference case	HeartMate 3: inflow cannula 20 mm, tip sharply cylindrical without bevel [PAPER-L3]; standard outflow graft 14 mm; the 10 mm alternative needed 1472 vs 1283 rpm per L/min [PAPER-L2].	SynCardia: atrial inflow connectors with 27 mm valve ports, outflow cannulae with 25 mm valve ports, velour covered driveline conduits [REG-1]. BiVACOR: inlet ports about 18 to 20 mm (patent); as-implanted cuffs and grafts not published.
Size and fit limits	HeartMate 3 pump 69 x 30 mm, 200 g with hardware; up to 10 L/min.	SynCardia: BSA 1.7 to 2.5 m ² inclusion, under 1.7 or sternum to T10 under 10 cm contraindicated; trial patients 86% male, mean age 51, 85.3 kg, 2.0 m ² . BiVACOR: over 1.4 m ² (manufacturer); fitting study spine to sternum 11 to 18 cm.
Pressure duty	Left rise 58 to 106 mmHg implied; must deliver the reference man's 6.5 L/min at rest, so a 5 L/min design point is below it.	Left as LVAD; right 9 to 19 mmHg implied, and the right side must tolerate mean PA of 19.4 to 29.4 mmHg in mild exercise. SynCardia drive pressures (180 to 220, 50 to 70 mmHg) are air pressures on a diaphragm, not comparable to a rotary pump's steady rise.

The Thai fit question. The illustrative Thai man's 1.77 m² sits only 0.07 m² above the pulsatile TAH's 1.7 m² floor. The rotary TAH's claimed 1.4 m² floor clears it. A device sized for the ICRP reference man at 1.90 m² is sized for someone larger than the likely Thai recipient. This is the single most important consequence of the anthropometry for CardiaNova, and it rests on a derived number.

5. How the numbers were obtained and checked

Method

Web search for candidates, then primary sources only. PDFs that the fetch tool returned as bytes were saved and converted locally with pdftotext. PubMed's cookie wall was bypassed through the Europe PMC REST API, which returns abstracts and open access full text without a consent gate. Patents were read as text through Google Patents. Every identifier used to fetch a record came from a search result or a retrieved document, never from memory; the one exception (the Mosteller citation) was confirmed afterwards. Search-engine summaries that offered numbers not traceable to a document (an 18.6 mm HeartMate 3 impeller, a 30 to 35 mm SVC) were rejected and are recorded as rejected.

Accuracy check, run 17

Every source key resolves in every file. Every derived figure recomputes. Zero em-dashes, middle dots or entities. Every value that could be re-fetched matched its source: 14 bibliographic records, 12 abstracts, 11 open access full texts, both patents, the manufacturer site, the IEEE Spectrum article, two FDA documents, two StatPearls chapters, OpenStax, the ISMB14 paper, two Springer chapter records and JNC 7. The check found two wrong sentences, two claims not in their cited source, one citation covering two documents, five incomplete citations, and one duplication.

Fixes, run 18

Problem	Fix
Thai fit sentence said the 1.7 m ² floor 'is at or above' 1.77 m ²	Reworded. 1.77 sits 0.07 above the floor.
'Narrowed to 48 to 52 mm in the later filing'	Both patents list the same brackets. Corrected in both BiVACOR files and on the web page; recorded in the honest-notes section.
'Five female and five male' attributed to the Emmanuel abstract	The abstract gives age, BMI and aetiology, not sex; the full text is closed access; no other record states it. Removed, replaced with mean age 53 and mean BMI 28.
'July 2024' attributed to the Shah abstract, which gives no month	Sourced to the joint Texas Heart Institute and BiVACOR press release of 25 July 2024: implant on 9 July 2024. New key [PRESS-1].
REG-1 cited one FDA document for facts from two	Both documents listed with URLs: P030011b (SSED) and P030011c (labelling), facts split between them.
Rogers 2013 full-text figures unverified	Full text fetched from PMC; SD 3.9, n 1767, age 49.8, measurement level confirmed.
ICRP 89 not re-fetched	Still not reachable (publisher 403). Citation says so. Values unchanged, to be ticked off by someone with the PDF.
Five incomplete citations; combined file could drift	PMID, PMC, volume and pages added. BiVACOR.md regenerated as the exact concatenation. Page rebuilt; publishing needs Ton.

Still open

Gap	What it would take
Mean weight and BSA of Thai adult men from a national survey	The NHES 6 report chapter with height and weight, read in a browser or with Thai OCR. Under an hour with access.
Thai vessel dimensions	No Thai or Southeast Asian CT reference study found.
Resting wedge pressure as a measured mean and SD in a healthy cohort	Kovacs 2009 full text, which returned 403 here. One retry from a university network.
ICRP 89 re-verification; Emmanuel 2022 full text	Library access. The sex split can go back in if the full text states it.
BiVACOR unpublished items (rotor mass, prime volume, cuffs, power, reliability)	QUT ePrints copies of Timms 2008 and the Greatrex thesis, and two Springer chapters, all paywalled or 403 from here.

6. Using this against CardiaNova

Inputs go in params.py, tagged, never inside a module. Anything taken from these files is reference data about someone else's device or about the population; it is not a CardiaNova measurement and it validates nothing CardiaNova has built. The project's own work remains design exploration with no hardware tested. Quoting a BiVACOR number next to a CardiaNova number does not turn either into device evidence. params.py currently carries clinical inputs of 5.0 L/min, 100 mmHg, 15 mmHg and 75 bpm as round numbers without citation; section 3 of the heart data file gives sources those inputs could cite. Whether to change them is Ton's decision.

7. References

BiVACOR file

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- [PAPER-13] Kleinheyder M et al. BiVACOR total artificial heart and future concepts. In: Mechanical Circulatory Support. Springer 2023. Not retrieved.
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- [REG-1] FDA PMA P030011, SynCardia CardioWest TAH-t: P030011b.pdf (SSED) and P030011c.pdf (labelling), accessdata.fda.gov. [REG-2] FDA PMA P160054, HeartMate 3, approved 23 August 2017; contains no dimensions.
- [TEAM-MAG-1] Greatrex N, Kleinheyder M, Nestler F, Timms D. This maglev heart could keep cardiac patients alive. IEEE Spectrum, 22 August 2019.
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Heart design data file

- [ICRP-1] ICRP Publication 89. Basic anatomical and physiological data for use in radiological protection: reference values. Ann ICRP 2002;32(3-4). Not re-fetched in the check.
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Design exploration, not validated device evidence. Every figure above is about another team's device or about a population, carries a source key in the underlying file, and cannot support any clinical or regulatory statement about CardiaNova.