

Safe Placement of a Micro-Electromechanical Systems (MEMS), Levonorgestrel Releasing Contraceptive: Cadaver and Porcine Studies

Elizabeth Proos

Daré Bioscience, Inc

Jeffrey Kalish

Boston University Chobanian & Avedisian School of Medicine

Brian J. Carmine

Boston University, Chobanian & Avedisian School of Medicine

Nicolas Pacelli

Daré Bioscience, Inc

Andrea Ries Thurman

athurman@darebioscience.com

Daré Bioscience, Inc

Research Article

Keywords: Contraceptive Implant, Levonorgestrel, Insertion Safety, Porcine Study, Cadaveric Anatomy Dissection, Preclinical Research

Posted Date: October 23rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11063684/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: Competing interest reported. EP, NP, and AT are paid employees of Daré Bioscience, Inc. and hold stock options or stock. JK and BC received funding from the NICHD for study-specific activities.

Abstract

In order to develop safe insertion criteria for future clinical studies of a levonorgestrel (LNG) releasing, wirelessly enabled micro-electromechanical system (MEMS)-based drug delivery device, we performed two pre-clinical studies in cadaver arms and pigs. Four female cadaver upper arms were dissected to assess the proposed insertion location, spatial orientation, and proximity to major muscle and neurovascular anatomy. Eight additional cadaver arms were dissected to assess insertion variables (incision depth, width, length, pocket creation). Twenty-four placebo MEMS devices were inserted sub-dermally into the backs of four miniature Yucatan pigs (6 devices per pig). Over a 2-to-4-month postoperative period, wound healing, device migration, and clinical observations were recorded. At removal, tissue capsule quality and tissue adhesions were evaluated. The target medial upper arm insertion site was 8–10 cm proximal to the medial epicondyle toward the axilla and 4–6 cm posterior to the brachial groove. Target insertion width (20 mm), depth (4 mm), and pocket length (51 mm) were defined. Porcine insertions were completed over 6–11 minutes with minimal bleeding. All sites healed well with no device migration over 2–4 months. After removal, tissue capsules were well formed and consistent with the expected normal healing response to a foreign body. These studies confirm the feasibility of safe insertion of the LNG MEMS device in the upper arm and a normal healing response to the device materials in live porcine tissue.

Introduction

Almost half of all pregnancies worldwide, estimated to be over 100 million annually, are unintended or mistimed (1–3). There has been a concerted effort in the United States (US) and worldwide to promote long-acting reversible contraception (LARC), such as the contraceptive implant, due to the high acceptability (4, 5) and continuation rates (6–8) and superior contraceptive efficacy (9–11). Progestin only implants have few absolute medical contraindications for use (12) and a quick return to fertility after removal (13). A disadvantage of all currently available contraceptive implants is that women must undergo an office surgical procedure to remove the non-biodegradable devices when they desire conception or if they want to discontinue their contraceptive method for various reasons. Many providers are now inserting the etonogestrel contraceptive implant immediately post-partum (8, 14, 15) or post abortion (16, 17) which reduces unintended, short interval repeat pregnancy but requires another minor surgical procedure in the immediate postpartum period.

Building upon the proven efficacy of the contraceptive implants, Daré Bioscience and collaborators developed a micro-electromechanical system (MEMS), implantable drug delivery device. The contraceptive MEMS product is designed to release levonorgestrel (LNG) for up to 10 years continuously. However, because this technology is capable of wireless communication through the skin, drug delivery may be paused without removal for extended periods of time to allow for conception, pregnancy and lactation and then re-started once the end user desires continued long-acting contraception, in lieu of surgical removal and re-insertion of a new device. End user data indicate that the autonomy offered by

this contraceptive delivery platform will be highly desirable to both women and health care providers (HCPs) (data on file with Daré Bioscience).

Critical to the successful uptake of any contraceptive or medication-releasing implant is the development of very specific guidelines for safe insertion and removal procedures. All current contraceptive implants are designed to be removed. Newer contraceptive implants have one or two rods, which are easier to remove than the six silastic rod system of Norplant. However, complications with new contraceptive implants have been reported, usually due to deep or sub-fascial placement (18–22). In fact, as contraceptive implants are introduced into new communities, capacity building to educate HCPs on proper insertion and removals is critical (23). Difficult removals or fear of the removal procedure can generate myths in communities implementing LARC that may prevent uptake (24).

Additional end user research indicated that the upper arm remains a desirable location for device insertion. Because this contraceptive MEMS delivery device is a different size than other contraceptive implants, the objectives of these experiments were (1) to describe and define the safest and most feasible insertion location in the upper arm and (2) to conduct porcine studies to describe safety endpoints associated with device insertion and removal.

Materials and Methods

Cadaver Studies

Prior to the conduct of the cadaver studies, the Daré Bioscience team and consulting general and vascular surgeons (authors BJC and JK respectively) met to review study goals and developed a study protocol and process flow and reviewed the literature on current contraceptive implant insertion procedures, upper arm anatomy, and potential implant insertion complications. The cadaver studies were conducted at Boston Bioskills Lab (Lexington, MA), which is a medical training services organization. Twelve cadaveric upper arms with or without attached scapula from nine females of varying age (33–81 years) and body mass index (BMI) ($20\text{--}42\text{ kg/m}^2$) were obtained. One surgeon worked on the even numbered specimens and one surgeon worked on the odd numbered specimens, at two separate operating tables in the same surgical suite. Arms were positioned on the operating table with elbow flexion to approximately 90 degrees. As shown in Fig. 1, the medial epicondyle (MEC) and brachial groove were located as anatomical landmarks for determining the target insertion location. Lines were marked at 8 and 10 cm from the medial epicondyle. Perpendicular lines were drawn which intersected the 8 and 10 cm marks and traveled posteriorly toward the triceps. The perpendicular lines were marked at the 4 and 6 cm points from the brachial groove. The arm circumference (cm), skin thickness (mm), and subcutaneous tissue thickness (mm) at the potential insertion sites were measured. The length of skin incisions and tissue pockets required to accommodate plastic, 3D printed prototype devices, which were the same size (15.5 mm wide, 50 mm long and 7 mm thick) and shape, with rounded, smooth edges were produced. After dissection of the overlying skin, a rectangular flap was created to measure and record the proximity of inserted prototypes to neurovascular structures of

interest (basilic vein, brachial artery, medial antebrachial cutaneous nerve, ulnar nerve, median nerve). Next, removal of the overlying skin and full anatomic dissection of the area of interest was performed and the anatomy was described and photographed as with the example shown in Fig. 2.

Members of the Daré Bioscience product development team attended both cadaver dissection sessions and assisted with photographing and videoing the dissections. The surgeons performed all dissections, measurements and notations regarding neurovascular structures or any notable findings without interference from the Daré Bioscience team. All staff members met in between the surgical sessions to review data and de-brief on any complications, noteworthy events and surgical approaches.

Porcine Studies: The porcine studies were conducted at Toxicon Corporation (Bedford, MA). The animal care and procedure protocol were approved by the Institutional Animal Care and Use Committee (IACUC) (study number 21-03853-N1). A total of 24 non-functional devices (Figures 3a, 3b) were inserted into the backs of four pigs (six devices per pig). The devices were constructed of representative tissue-contacting materials that will be used in the actual product construction (titanium, silicone, and biocompatible epoxy) and were the same size, shape, and dimensions as the mock devices used in the cadaver labs.

Devices were implanted in the para-lumbar region with three devices on each side (left and right). The device orientation was alternated such that in half of the devices the muscle facing surface was titanium and in the other half the muscle facing surface was silicone, to assess any differences in healing response with orientation. During the porcine procedures the following metrics were measured (1) total procedure time, (2) skin thickness, (3) insertion/ incision width, and (4) pocket depth (pocket length and distance from the device end to the incision after insertion) and recorded. Absorbable sutures were used to close the incisions after insertion. Animals were monitored daily from the day of insertions for wound healing, general health and body weight.

Two months post-insertion, two of the four pigs were humanely euthanized to retrieve the devices and tissue capsules. This process was repeated with the two remaining pigs after four months. The insertion sites and spatial orientation of the devices were described at euthanasia. Tissue capsules were removed and labeled based on the orientation of the device and histopathological assessment was performed.

Results

Cadaver Studies

The first dissections of six arms (samples 1–6) from three reproductive age women with high BMI (donors A, B and C) were performed on day 1 of the lab, and the second cadaver dissection of six arms (samples 7–12) from six women (donors D, E, F, G, H, I) with low BMI were performed on day 2. As shown in Table 1, the first six arms obtained from three reproductive age donors (mean 43 ± 7.9 years) all had a BMI of $> 35 \text{ kg/m}^2$ (mean $39 \pm 2.4 \text{ kg/m}^2$). The upper arms from the second set of six donors (mean age 64 ± 14.7 years) had a much lower mean BMI ($23.5 \pm 2.9 \text{ kg/m}^2$). Four arms (samples 1, 2, 3,

and 6) were dissected initially to assess the proposed arm location for insertion, spatial orientation, and proximity to major muscular and neurovascular structures. A rectangular flap was created to open and observe underlying neurovascular structures in the insertion area of interest. As each sample was dissected, the type and number of neurovascular structures were documented along with a qualitative assessment of proximity to the target area (Table 1). Based on the observed locations and depths of the major neurovascular structures, the proposed target insertion parameters were confirmed to be 8–10 cm from the MEC and 4–6 cm posterior to the brachial groove. Two additional arms (samples 4 and 5) were used to perform preliminary device insertions to assess safe implantation in identified target areas. To pinpoint the target insertion area, the distance from the MEC toward the axilla (first step in identifying target area) and distance from brachial groove toward the triceps was measured (second step to identifying target area). We also measured the actual distance from the MEC (first step in identifying target area) and actual distance from brachial groove (second step to identifying target area).

Table 1
Donor Information for Cadaver Arms and Surgical Observations

Sample Number	Donor Letter	Specimen	Age (Years)	BMI (kg/m ²)	Surgeon Observations
First Cadaveric Dissection Session (Three High BMI Donors)					
1	A	Left full arm	33	38	The basilic vein was observed deep to the fascia, approximately 4 cm from the brachial groove along with the medial antebrachial cutaneous nerve. The brachial artery and median nerve were much deeper and well below the fascia.
2	A	Right full arm	33	38	The basilic vein, medial antebrachial cutaneous nerve and brachial artery were observed and were deep to the fascia.
3	B	Left arm (no scapula)	46	37	The basilic vein and medial antebrachial cutaneous nerve were observed to be in the general area but again deep to the fascia and subcutaneous fat layer.
4	B	Right arm (no scapula)	46	37	The target location was directly between 8–10 cm from MEC and 4–6 cm posterior to the brachial groove. A 20 mm incision was made, and pocket created with a depth of between 5–10 mm. The device was inserted toward the axilla and could not be palpated after insertion. A large rectangular dissection area was opened to observe the device which again was well within the subcutaneous fat layer. The most superficial structure was the basilic vein and this was still deep to the fascia and subcutaneous fat layer.
5	C	Left arm (no scapula)	50	42	The target location for insertion was directly between 8–10 cm from MEC and 4–6 cm posterior to the brachial groove. A 15 mm incision was made, and pocket created with a depth of between 5–10 mm. The device was inserted toward the axilla and could not be palpated after insertion. A large rectangular dissection area was opened to observe the location of the device, which was squarely in the SQ fat layer. Both the basilic vein and brachial artery were observed to be under where the device was located and very deep. Fascia was opened to visualize the structures.
Second Cadaveric Dissection Session (Six Low BMI Donors)					
6	C	Right arm (no scapula)	50	42	All neurovascular structures were very deep and the fascial layer had to be opened to access them.

Sample Number	Donor Letter	Specimen	Age (Years)	BMI (kg/m ²)	Surgeon Observations
First Cadaveric Dissection Session (Three High BMI Donors)					
7	D	Left full arm	74	21	There was at least 1 cm subcutaneous fat thickness in the overall device location. The device was sitting posterior to the basilic vein and was superficial to it. The brachial artery was under another layer of fascia and much deeper than the device.
8	E	Right arm (no scapula)	61	20	All major neurovascular anatomy was subfascial. The median nerve runs with the brachial artery, which is near the brachial groove and, with the identified device location, the device will always be more posterior on the arm than these structures. Basilic vein was also more anterior than the device and the device was superficial to it.
9	F	Right full arm	67	28	This subject had a larger medial antebrachial cutaneous nerve with the basilic vein and the device was still well posterior to it in the target area (further from the brachial groove). Both the brachial artery and median nerve were much deeper under the fascia than the basilic vein as well.
10	G	Right full arm	38	25	The basilic vein and medial antebrachial cutaneous nerve were anterior to the device (closer to the brachial groove) and the device was again superficial to both. The brachial artery was much deeper below the fascia and far from the device.
11	H	Left arm (no scapula)	65	24	The basilic vein and medial antebrachial cutaneous nerve were about 1 cm below the skin surface and anterior to the device (closer to brachial groove). Brachial artery and median nerve were very deep below the fascia and near the brachial groove.
12	I	Left full arm	81	23	In this subject the basilic vein had a branch to it (not typical) that was closer to the device than any of the other subjects, but the device was still superficial to the vein. The brachial artery was well anterior to the device location (closer to the brachial groove).

Arm circumference, depth of subcutaneous fat layer and distance from axilla to MEC were recorded for all six higher BMI subjects studied to identify the target device insertion site (Table 2). Skin thickness was not easily measured and due to the large amount of subcutaneous fat was not considered to be a

relevant factor in identifying the target location. Due to the significant amount of subcutaneous fat in the first six samples, from the three higher BMI women, there were no suspected adverse complications with inserting the DARE-LARC1 product concept safely, avoiding all major neurovascular structures.

Table 2

Quantitative Measurements of Arm Characteristics from High BMI and Low BMI Donors to Inform Target Device Insertion Location.

Measurement	High BMI Premenopausal Donors (Samples 1–6 from Donors A, B and C)			Low BMI Postmenopausal Donors (Samples 7–12 from Donors D, E, F, G, H, I)		
	Range	Mean	Standard Deviation (% Relative Standard Deviation)	Range	Mean	Standard Deviation (% Relative Standard Deviation)
Arm Circumference (cm)	33–38	35.7	1.8 (5.1%)	20.5–29.5	25.1	3.5 (13.8%)
Subcutaneous fat thickness (mm)	16–25	20.7	3.1 (14.9%)	10–11	10.3	0.5 (5.0%)
Axilla – MEC distance (cm)	22–23	22.3	0.4 (1.9%)	21–21.5	21.3	0.4 (2.0%)
Distance from incision to MEC (cm)	8–10	9.2	0.8 (8.2%)	8–9	8.3	0.4 (4.9%)
Distance from incision to brachial groove (cm)	4–6	5.0	0.9 (17.9%)	5–5.5	5.2	0.3 (5.0%)
Incision width (mm)	20 (sample 4), 15 (sample 5)			15–22	19.3	2.7 (14.1%)
Incision depth (mm)	5–10 (samples 4 and 5)			2.5–7.5	4.3	1.8 (40.4%)
Insertion pocket length (mm)	Not recorded			50–55	50.8	2.0 (4.0%)
Distance from inserted device end to axilla (cm)	Not recorded			6–8	7.1	0.8 (11.3%)

Using the experience gained in the first cadaver lab and in consultation with our surgeons, we prioritized lower BMI profile (< 30) as it was crucial to confirm the target insertion location is viable across a broader BMI range. We specifically wanted to evaluate lower BMI subjects where insertion location may be more sensitive to the neurovascular anatomy due to less subcutaneous fat in the upper arm. It was also specified that we receive arms from six different donors (D – I) for the second cadaver lab (Table 1). Additional measurements were taken in the lower BMI samples to describe the location of the device with relationship to the length of the arm from MEC to axilla (Table 2).

Porcine Studies

Data from porcine studies are presented in Table 3. Minimal bleeding was observed for all 24 insertion procedures and insertion was relatively easy after the initial incision and pocket was created. All devices could be palpated after insertion, but none were observed to be visible under the skin or protruding. It was noted that pig skin is thicker than human skin and is generally stiffer in the para-lumbar region, likely making the insertions in pigs more difficult than would be expected in women. Absorbable sutures were used to close the incisions after insertion. All animals gained weight through the course of the study (Supplemental Fig. 1) and incision wounds healed without issue.

Table 3
Quantitative Metrics of Porcine Insertion Procedures

Metric	Range	Average	Standard Deviation (% Relative Standard Deviation)
Total procedure time (minutes)	4–11	6.5	1.8 (28.1%)
Skin thickness (mm)	3–6	4.4	0.8 (17.6%)
Incision width (mm)	22–28	25.1	1.9 (7.7%)
Pocket depth (mm)	10–25	18.1	3.2 (17.8%)
Insertion pocket length (mm)	55–70	61.7	4.3 (7%)
Distance from device end to incision (mm)	2–5	2.6	1.1 (41.8%)

In all cases the device insertion sites were well-healed. All of the devices maintained their original orientation with respect to muscle contact surface (titanium or silicone). There was no clinical evidence of inflammation, and the tissue capsules were well-formed, thin and vascular. Tissue capsules were opened to retrieve the devices with no evidence of adhesion to the device materials. The capsules were marked to identify tissue contacting titanium vs. silicone and fixed in a 10% neutral buffered formalin solution prior to being sectioned and stained for a histopathological assessment. Tissue sites adjacent to both the titanium and the silicone materials were consistent with typical local responses following implantation of a foreign inert material.

Discussion

The product prototypes were successfully placed and avoided neurovascular structures in the upper arms from all cadavers. Despite a significant difference in arm circumference between the higher and lower BMI donors, there remained a substantial amount of subcutaneous fat posterior to the brachial groove in all subjects. Insertion into this layer at the target zone of 8–10 cm from the MEC and 4–6 cm posterior to the brachial groove avoided all major neurovascular structures. Preliminary insertion criteria

were defined with an incision width approximately 20 mm, depth of approximately 4 mm, and insertion pocket length of 51 mm.

Our target insertion location for the upper arm is consistent with recent changes in the recommended upper arm insertion location for the etonogestrel (ETG) contraceptive implant. This implant (Implanon) was first approved by the US Food and Drug Administration in 2006. In 2011, barium was added to the implant (re-branded as Nexplanon) to allow for visualization on radiographs, and the inserter was re-designed with additional safety features to reduce sub-fascial insertions. The recommended insertion site for the ETG implant was initially at the inner side of the non-dominant upper arm, overlying the sulcus between the biceps and triceps, approximately 8–10 cm. from the MEC (25). Although rare, there were reports of implant migration into the vasculature, chest wall and pulmonary artery, likely due to insertion or migration into the neurovascular bundle, or into the basilic vein, in the sulcus between the biceps and triceps (26). Therefore, in 2018, the manufacturer of Nexplanon recommended that the implant be inserted 8–10 cm from the MEC and 3–5 cm posterior to the brachial groove, toward the triceps muscle (27). The ETG implant is much smaller than our MEMS device (4 cm long and 2 mm in diameter), and so our anatomic dissections found that a target location of 4–6 cm posterior to the brachial groove, rather than the 3–5 cm recommended for the ETG implant, was the safest site to avoid neurovascular structures.

We found that the average incision width needed to create a pocket for the MEMS device was approximately 2 cm. This small incision could safely be closed with a skin glue rather than sutures (28).

Strengths of this study were the ability to have vascular and general surgeons who are extremely familiar with the vulnerable neurovascular structures perform these dissections in a range of specimens from high and low BMI women. With the recent change in insertion recommendations for the ETG implant, it is necessary to do these surgical dissections to ensure that the new device may be safely inserted. We have explored other anatomic locations for this device, including the abdomen. After weighing ample input from HCPs from various countries and clinic service levels, we believe that the upper arm is the most feasible and familiar site for HCPs and patients.

We plan to build upon the data obtained from these initial dissections and test various device inserters during the next experiments. A limitation of this study was that the devices were inserted using various clamps and instruments available in the operating room, but not in the outpatient clinic setting. We recognize that for HCPs to feel comfortable implementing this product and procedure in their practices, we must design a product inserter which makes the insertion procedure safe, easy to perform and as comfortable for the patient as possible.

In conclusion, these studies support that the MEMS device can be safely inserted into the medial upper arm, avoiding neurovascular structures. The porcine studies support that healing after device insertion was adequate, with no complications.

Declarations

Porcine Studies

The animal care and procedure protocol were approved by the Institutional Animal Care and Use Committee (IACUC) (study number 21-03853-N1).

Declarations Competing Interests

EP, NP, and AT are paid employees of Daré Bioscience, Inc. and hold stock options or stock. JK and BC received funding from the NICHD for study-specific activities.

Funding:

Daré Bioscience, Inc. (Daré) received funding from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD) of the National Institutes of Health (NIH) (1R43HD107685-01) to support the study activities. **Competing Interests:** EP, NP, and AT are paid employees of Daré Bioscience, Inc. and hold stock options or stock. JK and BC received funding from the NICHD for study-specific activities.

Author Contribution

Elizabeth Proos Conceptualization, Methodology, Validation, Supervision, Project Administration, Resources, Writing – Review and Editing
Jeffrey Kalish MD: Performance of cadaver dissections, data review, data curation, formal analysis, writing – review and editing
Brian Carmine MD: Performance of cadaver dissections, data review, data curation, formal analysis, writing – review and editing
Nicolas Pacelli: Conceptualization, Methodology, Validation, Supervision, Project Administration, Resources, Writing – Review and Editing
Andrea Ries Thurman MD: Validation, Supervision, Project Administration, Data analysis, Resources, Writing – Original Draft

Data Availability

Data are available upon request to the authors. The data were not deposited into a repository.

Authors:

Jeffrey Kalish MD: Performance of cadaver dissections, data review, data curation, formal analysis, writing – review and editing

Brian Carmine MD: Performance of cadaver dissections, data review, data curation, formal analysis, writing – review and editing

Nicolas Pacelli: Conceptualization, Methodology, Validation, Supervision, Project Administration, Resources, Writing – Review and Editing

Andrea Ries Thurman MD: Validation, Supervision, Project Administration, Data analysis, Resources, Writing – Original Draft

Clinical Trial Number is not applicable. Informed consent statement is not applicable for the cadaver studies.

References

1. Kott A. Rates of Unintended Pregnancy Remain High In Developing Regions. *Int Perspect Sex Reproductive Health* 2011;37(1).
2. Finer LB, Zolna MR. Declines in Unintended Pregnancy in the United States, 2008–2011. *N Engl J Med*. 2016;374(9):843–52.
3. Singh S, Sedgh G, Hussain R. Unintended pregnancy: worldwide levels, trends, and outcomes. *Stud Fam Plann*. 2010;41(4):241–50.
4. Hubacher D, Spector H, Monteith C, Chen PL, Hart C. Long-acting reversible contraceptive acceptability and unintended pregnancy among women presenting for short-acting methods: a randomized patient preference trial. *Am J Obstet Gynecol*. 2017;216(2):101–9.
5. Mestad R, Secura G, Allsworth JE, Madden T, Zhao Q, Peipert JF. Acceptance of long-acting reversible contraceptive methods by adolescent participants in the Contraceptive CHOICE Project. *Contraception*. 2011;84(5):493–8.
6. Mark A, Sonalkar S, Borgatta L. One-year continuation of the etonogestrel contraceptive implant in women with postabortion or interval placement. *Contraception*. 2013;88(5):619–23.
7. Howard DL, Ford A, Ceballos S, Volker KW. Temporal Trends in the Uptake and Continuation of the Etonogestrel Implant in a Large Private Practice Setting. *J Womens Health (Larchmt)*. 2018;27(2):191–5.
8. Vieira CS, de Nadai MN, de Carmo M, Braga LS, Infante GC, Stifani BF et al. BM, Timing of postpartum etonogestrel-releasing implant insertion and bleeding patterns, weight change, 12-month continuation and satisfaction rates: a randomized controlled trial. *Contraception*. 2019;100(4):258–63.
9. Beerthuizen R. Safety and efficacy of the subdermal etonogestrel contraceptive implant Implanon((R)). *J Fam Plann Reprod Health Care*. 2017;43(2):118.
10. Thaxton L, Lavelanet A. Systematic review of efficacy with extending contraceptive implant duration. *Int J Gynaecol Obstet*. 2019;144(1):2–8.
11. Ali M, Akin A, Bahamondes L, Brache V, Habib N, Landoulsi S, et al. Extended use up to 5 years of the etonogestrel-releasing subdermal contraceptive implant: comparison to levonorgestrel-releasing subdermal implant. *Hum Reprod*. 2016;31(11):2491–8.

12. World Health Organization. Medical Eligibility Criteria for Contraceptive Use 2015, Fifth Edition. 2015.
13. Bhatia P, Nangia S, Aggarwal S, Tewari C. Implanon: subdermal single rod contraceptive implant. *J Obstet Gynaecol India*. 2011;61(4):422–5.
14. Wilson S, Tennant C, Sammel MD, Schreiber C. Immediate postpartum etonogestrel implant: a contraception option with long-term continuation. *Contraception*. 2014;90(3):259–64.
15. Tang JH, Lemani C, Nkambule J, Talama G, Banda C, Zgambo W, et al. Two-year contraceptive continuation rates among immediate postpartum implant users at a district hospital in Malawi: a prospective cohort study. *Contraception*. 2018;98(3):220–2.
16. Barros Pereira I, Carvalho RM, Graca LM. Intra-abortion contraception with etonogestrel subdermal implant. *Eur J Obstet Gynecol Reprod Biol*. 2015;185:33–5.
17. Madden T, Eisenberg DL, Zhao Q, Buckel C, Secura GM, Peipert JF. Continuation of the etonogestrel implant in women undergoing immediate postabortion placement. *Obstet Gynecol*. 2012;120(5):1053–9.
18. Chen MJ, Creinin MD. Removal of a Nonpalpable Etonogestrel Implant With Preprocedure Ultrasonography and Modified Vasectomy Clamp. *Obstet Gynecol*. 2015;126(5):935–8.
19. Chevreau J, Krief D, Abou Arab O, Zitoun M, Foulon A, Sergeant F, et al. Factors associated with removal difficulties of etonogestrel-containing contraceptive implants (Nexplanon((R))). *Eur J Obstet Gynecol Reprod Biol*. 2018;224:81–4.
20. Matulich MC, Chen MJ, Schimmoeller NR, Hsia JK, Uhm S, Wilson MD, et al. Referral Center Experience With Nonpalpable Contraceptive Implant Removals. *Obstet Gynecol*. 2019;134(4):801–6.
21. Reed S, Do Minh T, Lange JA, Koro C, Fox M, Heinemann K. Real world data on Nexplanon(R) procedure-related events: final results from the Nexplanon Observational Risk Assessment study (NORA). *Contraception*. 2019;100(1):31–6.
22. Petro GA, Spence T, Du Plessis JP, Gertz AM, Morroni C. Migration of etonogestrel contraceptive implants: Implications for difficult removals services need in southern Africa. *S Afr Med J*. 2019;109(8):559–61.
23. Pleaner M, Morroni C, Smit J, Lince-Deroche N, Chersich M, Mullick S, et al. Lessons learnt from the introduction of the contraceptive implant in South Africa. *S Afr Med J*. 2017;107(11):933–8.
24. Pillay D, Chersich M, Morroni C, Pleaner M, Adeagbo OA, Naidoo N, et al. User perspectives on Implanon NXT in South Africa: A survey of 12 public-sector facilities. *S Afr Med J*. 2017;107(10):815–21.
25. FDA. Full Prescribing Information Implanon Package Insert. https://www.accessdata.fda.gov/drugsatfda_docs/label/2006/021529lbl.pdf 2006; Accessed 26 JAN 2024.
26. Kang S, Niak A, Gada N, Brinker A, Jones SC. Etonogestrel implant migration to the vasculature, chest wall, and distant body sites: cases from a pharmacovigilance database. *Contraception*. 2017;96(6):439–45.

27. FDA. Prescribing Information for Nexplanon Etonogestrel Contraceptive Implant.
https://www.accessdata.fda.gov/drugsatfda_docs/label/2019/021529s018lbl.pdf 2018;Accessed 26 JAN 2024.
28. Daykan Y, Sharon-Weiner M, Pasternak Y, Tzadikévitch-Geffen K, Markovitch O, Sukenik-Halevy R, et al. Skin closure at cesarean delivery, glue vs subcuticular sutures: a randomized controlled trial. Am J Obstet Gynecol. 2017;216(4):e4061–5.

Figures

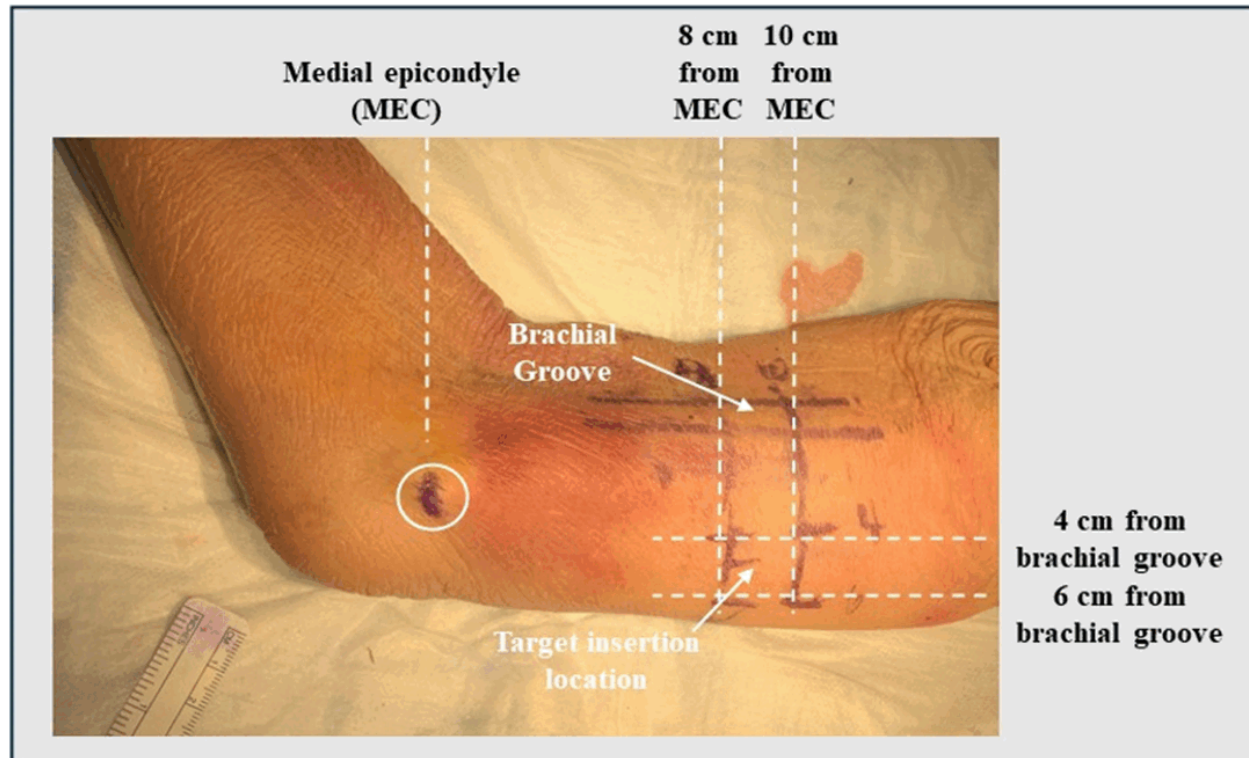


Figure 1. Representative image of measurements used to determine the target insertion location

Figure 1

See image above for figure legend

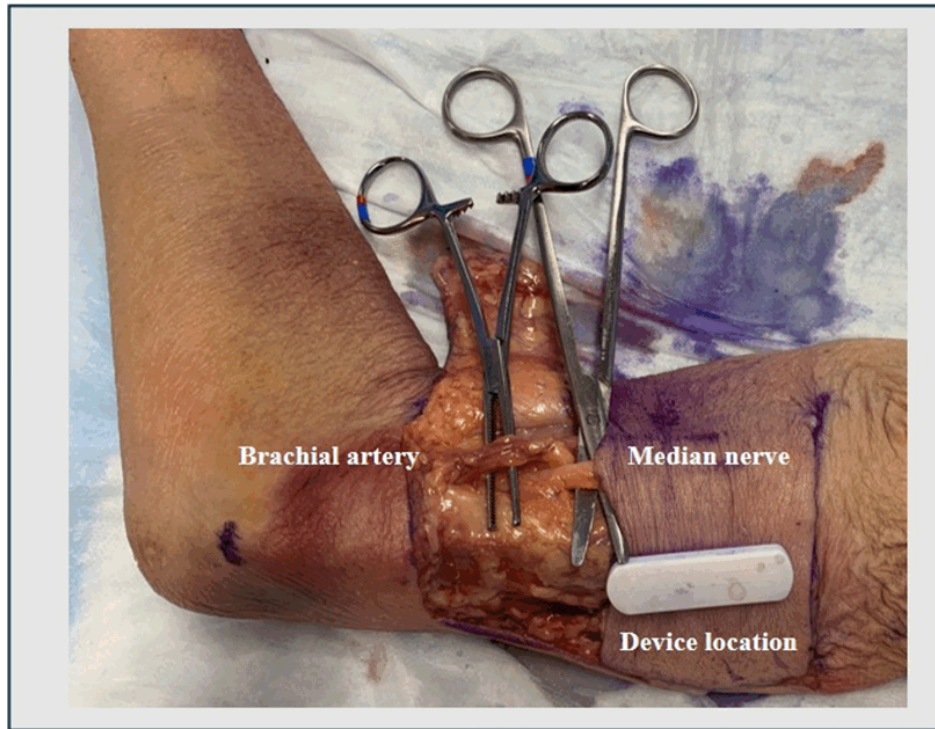


Figure 2: Representative post-dissection image showing the insertion location relative to major neurovascular structures such as the brachial artery and median nerve.

Figure 2

See image above for figure legend

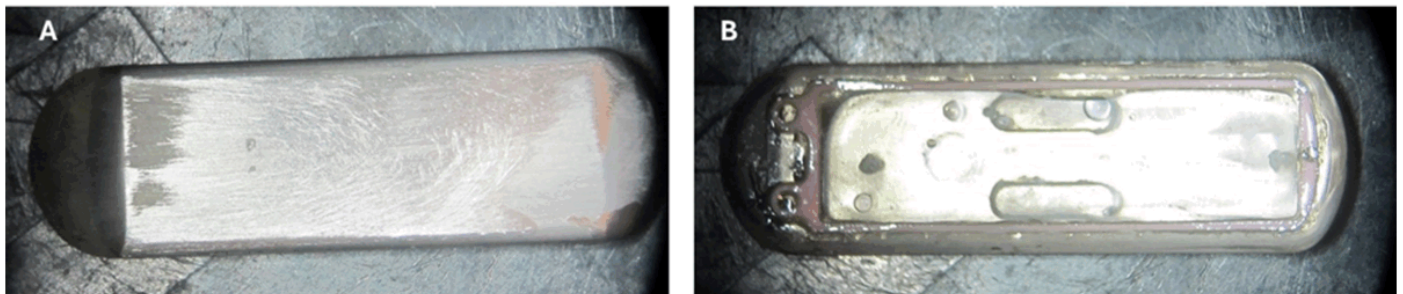


Figure 3: Example non-functional devices implanted in pig model A) titanium side and B) silicone and epoxy side

Figure 3

See image above for figure legend

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [20260625SupplementalFigure1CadaverLabManuscript.tif](#)