Renal Vascular Clamp Placement: A Potential Cause of Incomplete Hilar Control during Partial Nephrectomy

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Abbreviations and Acronyms

LPP = leak point pressure

PN = partial nephrectomy

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Purpose: Previous benchtop studies have shown that robotic bulldog clamps provide incomplete vascular control of a Penrose drain. We determined the efficacy of robotic and laparoscopic bulldog clamps to ensure hemostasis on the human renal artery. The effect of clamp position on vascular control was also examined.

Materials and Methods: Fresh human cadaveric renal arteries were used to determine the leak point pressure of 7 bulldog clamps from a total of 3 manufacturers. Five trials were performed per clamp at 4 locations, including the fulcrum, proximal, middle and distal positions. Comparison was done using the Kruskal-Wallis test with $p < 0.05$ considered significant.

Results: None of the bulldog clamps leaked at a pressure less than 215 mm Hg when applied at the proximal, middle or distal position. In general leak point pressure decreased as the artery was positioned more distal along the clamp. The exception was when the vessel was placed at the fulcrum position. At that position 80% to 100% of trials with the Klein laparoscopic, 100% with the Klein robotic (Klein Robotic, San Antonio, Texas) and 60% to 80% with the Scanlan robotic (Scanlan International, Saint Paul, Minnesota) clamp leaked at pressure below 215 mm Hg.

Conclusions: Each vascular clamp adequately occluded flow at physiological pressure when placed at the proximal, middle or distal position. Furthermore, these results demonstrate that there is leakage at physiological pressure when the artery is placed at the fulcrum of certain clamp types. These results suggest that applying a bulldog clamp at the fulcrum could potentially lead to inadequate vessel occlusion and intraoperative bleeding.

Key Words: kidney neoplasms, nephrectomy, hemostasis, surgical instruments, minimally invasive surgical procedures

LAPAROSCOPIC and robotic vascular bulldog clamps are commonly used to achieve vascular control of the renal hilum during minimally invasive PN.[1,2] Clamping the hilar vessels reduces blood loss and permits better visualization during the critical steps of tumor resection and parenchymal reconstruction. Inadequate vessel occlusion by these clamps can lead to poor oncologic outcomes and may potentially increase warm ischemia time. Several studies have described cases of intraoperative hemorrhage in PN that were attributable to inadequate arterial occlusion by bulldog

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clamps.[3–6] Problems with inconsistent and inadequate hemostasis when using a single bulldog clamp have led to the practice of applying multiple clamps along the renal artery and the use of handheld or laparoscopic Satinsky clamps instead of bulldog clamps.[7–10]

A previously published series performed on a porcine artery model demonstrated significant differences in LPP and jaw force between Aesculap and Klein laparoscopic bulldog clamps.[11] In a recent study Le et al evaluated clamping force and leak point pressure for robotic and laparoscopic vascular bulldog clamps using a Penrose drain model.[12] That study showed that robotic bulldog clamps generated significantly less force than laparoscopic bulldog clamps and permitted leakage at physiological blood pressures.

To our knowledge no previous study has determined the ability of laparoscopic and robotic bulldog clamps to prevent bleeding when applied to the human renal artery. We evaluated the efficacy of different laparoscopic and robotically applied bulldog clamps using a human renal arterial model. The effects of different application positions were also examined.

MATERIALS AND METHODS

A benchtop model was created to measure the LPP of 7 bulldog clamps (figs. 1 and 2). Three fresh human renal arteries were obtained at autopsy and used within 6 hours of harvest. The section of artery removed from each cadaver extended from the abdominal aorta to the branch point at the renal hilum. The arteries were taken from adult males 25 to 40 years old. The final arteries were 25 to 40 mm long and 5 to 7 mm in diameter. Arteries were used for multiple trials that were randomized between vessels.

The proximal end of the artery was cannulated with a 10Fr open-ended catheter that was secured in place with a silk tie. At the distal end of the artery a bulldog clamp was applied 5 mm from the end of the vessel. An automated IVAC® syringe pump was used to infuse normal saline at 50 ml per minute. Pressure was measured to 300 mm Hg using a standard calibrated arterial line monitor (Medical Data Electronics, Arleta, California). All pressures above 300 mm Hg were measured with a digital pressure gauge (Ashcroft, Stratford, Connecticut). Infusion was maintained while intra-arterial pressure increased until leakage was visualized from the distal arterial end. Pressure at this point was recorded as the clamp LPP.

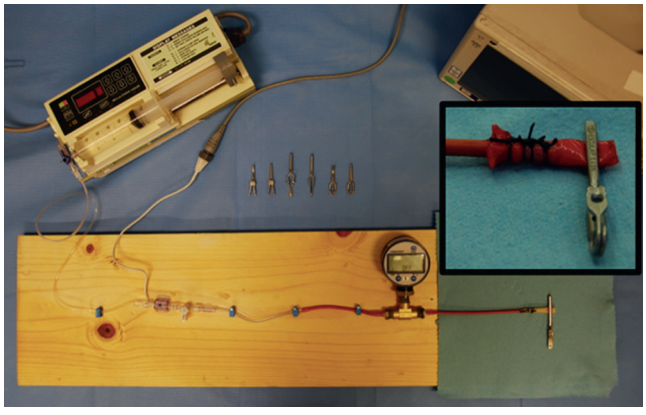

Figure. 1. Experimental setup. Inset, clamped cadaver renal artery.

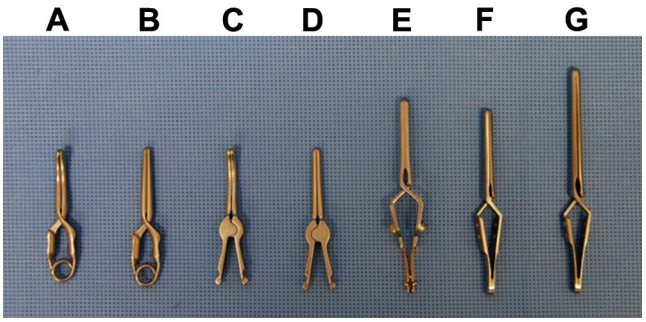

Figure. 2. Bulldog clamps used in study, including Aesculap 25 mm curved (*A*) and straight (*B*) laparoscopic, Scanlan 25 mm curved (*C*) and straight (*D*) robotic, and Klein straight 25 mm robotic (*E*) and laparoscopic (*F*), and 45 mm laparoscopic (*G*) clamps.

Three brands of vascular bulldog clamps were tested in this study, including 1) a Klein 25 mm straight robotic, a 25 mm straight laparoscopic and a 45 mm straight laparoscopic bulldog clamp, 2) an Aesculap 25 mm straight laparoscopic and a 25 mm curved laparoscopic bulldog clamp (Aesculap, Center Valley, Pennsylvania), and 3) a Scanlan 25 mm straight robotic and a 25 mm curved robotic bulldog clamp (fig. 2). Four locations along the clamp were tested, including the fulcrum, proximal, middle and distal positions (fig. 3). Each bulldog clamp was noted to have a gap at the fulcrum where the closing

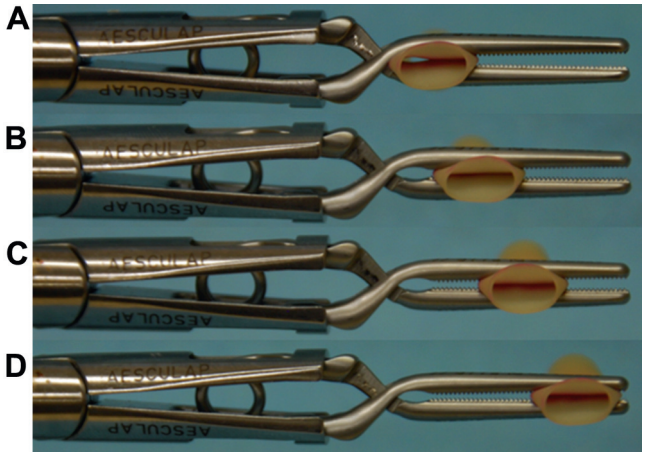

Figure. 3. Clamp placement positions demonstrated with Aesculap bulldog clamp applied on $^{1}/_{4}$-inch Penrose drain, including fulcrum (*A*), proximal (*B*), middle (*C*) and distal (*D*) positions.