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# Laparoscopic Live Donor Nephrectomy: A Step Forward in Kidney Transplantation?

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## ABSTRACT

Open donor nephrectomy for live donor kidney transplantation is a safe procedure that has been used for more than 30 years with excellent results. Laparoscopic donor nephrectomy is a relatively new technique that has the potential of decreased postoperative pain, less incisional morbidity, and shorter recovery time. Furthermore, it has been reported that this potentially less traumatic approach increases the number of potential live donors. This review article focuses on the currently used laparoscopic techniques in live kidney donation as well as the controversy regarding its efficacy, safety, and future.

**Key Words:** Laparoscopic live donor nephrectomy, Laparoscopy, Kidney transplantation.

## INTRODUCTION

Live donor renal transplantation is considered the ideal treatment for patients with end-stage renal failure. Compared with long-term dialysis, kidney transplantation offers an improved quality of life, reduced death rate, and much lower cost.[1-3] Compared with cadaveric kidney transplantation, live donor transplantation results in significantly better patient and graft survival.[4] The estimated half-life (the time after which 50% of transplanted kidneys are still functioning) of cadaver kidneys is 8.6 years, but for live donor kidneys it is 14.7 years.[5] The standard retroperitoneal open donor nephrectomy (ODN) has been the most commonly used technique for kidney donation with more than 30 years of proven safety and effectiveness. It is considered the "gold standard" to which other nephrectomy methods should be compared.[6] However, ODN can sometimes result in significant postoperative pain and discomfort due to the extensive flank incision and is sometimes related to prolonged hospitalization and late return to normal activity.

Laparoscopic nephrectomy was initially described in 1991 by Clayman et al.[7] Yang et al[8] reported in 1994 the first endoscopic (retroperitoneoscopic) approach for the live donor nephrectomy. At the same time, Gill et al[9] described successive experimental laparoscopic donor nephrectomy (LDN) transplantation in a porcine model. Eventually, the University of Maryland[10,11] and John Hopkins University[12,13] were the pioneers that further developed the laparoscopic technique for live donor nephrectomy. Following that, the technique became increasingly popular, and today, LDN is performed in many centers around the world.

## DONOR SELECTION

Detailed preoperative evaluation of the renal vascular anatomy is critical for the planning of the operative approach in LDN. Dual-phase spiral computed tomography (CT) combined with 3-dimensional CT angiography[14,15] or magnetic resonance imaging (MRI) angiography[16] are noninvasive techniques that provide depiction of the renal vascular anatomy comparable to that of standard angiography. Donors with serious anatomical abnormalities, such as horseshoe or ectopic kidneys,

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should be excluded from undergoing LDN. Relative contraindications to LDN are a history of multiple intraabdominal operations and renal vascular complexity. Multiple renal vessels are present in about 20% of cases,[17] and are usually small and prone to vasospasm carrying a great risk of intraoperative renal ischemia. Sasaki et al[18] considered that kidneys with more than 2 arteries must not be retrieved laparoscopically. Double ureters, age, and obesity are not considered exclusion criteria from laparoscopic donation,[18-20] In a comparative study, Kuo et al[20] found no differences in outcome after LDN in obese donors (BMI>31).

## PRINCIPLES OF THE LAPAROSCOPIC APPROACH

The operation is performed with the patient under general anesthesia in the contralateral standard flank or slightly modified flank position.

The pneumoperitoneum can have a detrimental effect on pulmonary function and renal perfusion. The increased intraabdominal pressure results in decreased renal perfusion and urine output that is due to central venous compression.[21-23] London et al[22,24] demonstrated that pneumoperitoneum-induced renal function impairment can be eliminated by aggressive volume loading. Laparoscopic donors should receive generous intravenous administration of crystalloid fluids during the operation to maintain diuresis of at least 300 mL/h. Mannitol, frusemide, and a renal dose of dopamine can also be used to achieve this goal. Johns Hopkins Hospital's practice is to administer 5 to 7 liters of crystalloid intravenously in addition to 12.5 mg of mannitol and 40 mg of frusemide intraoperatively.

Renal artery vasospasm due to surgical manipulations (traction or dissection) presents an additional risk of renal ischemia and is not unusual during LDN, especially in cases with multiple renal arteries. Early volume load, keeping dissection of the renal artery near the aorta where the diameter of the artery is the largest, and local application of papaverine and lidocaine to the surface of the renal artery may prevent the vasospasm.[18,25] Transient prophylactic systemic heparinization with 100 U/kg is administered just before kidney removal and is then reversed with 1 mg/kg of protamine.[26] Excessive ureteric tenting during dissection can lead to stripping of the ureteric vessels and subsequent ureteric necrosis. Use of an ultrasonic scalpel for dissection of the ureter decreases the chance of thermal injury.[27] The ureter must be mobilized with the gonadal vein and all the intervening tissue in a plane medial to the gonadal vein while care must be taken to avoid lateral femoral cutaneous nerve injury.[18,25,28]

In LDN, warm ischemia time tends to be longer than that in the open procedure[29] because of the more delicate extraction process of the kidney. Proper planning of the extraction process can restrict this undesirable warm ischemia time interval.

As revealed in the published literature, the left LDN is more feasible and preferable.[17] Laparoscopic right nephrectomy is considered much more difficult because of the right renal vein shortness and the proximity of the right liver lobe. The use of the Endo-GIA stapler for the division of the short right renal vein results in an additional loss of 1.0 cm to 1.5 cm of vein length, which makes its anastomosis to the recipient difficult. However, sometimes right kidney procurement is clearly advantageous because of the donor's vascular configuration. In the case of a right donor LDN, Berney et al[26] recommend the use of an Endo-TA instead of the classic Endo-GIA stapling device. Endo-TA allows the stapling of the renal vein right at its junction with the vena cava and the gaining of some extra millimeters of vein length due to the lack of a staple line on the kidney side.

## CURRENT LIVING DONOR NEPHRECTOMY TECHNIQUES

Transperitoneal Left Laparoscopic Donor Nephrectomy

In the classic left LDN, the surgical dissection is done through 4 small laparoscopic operating ports, ranging in size from 0.5 to 1.2 cm. The port for the video endoscope is placed either at the umbilicus[13] or anterior superiorly.[30] Additional ports are positioned midway between the umbilicus and the anterior superior iliac spine, in the epigastrium and in the flank at the posterior axillary line.

Initially, the left colonic flexure is dissected and mobilized medially to expose the anterior surface of Gerota's fascia. Tracing the gonadal vein facilitates the identification of the renal vein. The branches of the renal vein (adrenal, gonadal, and lumbar) are divided between clips. The renal artery is then exposed and dissected free from the lymphatic tissue. Maximum arterial length should be obtained by completely dissecting the renal artery to its proximal origin at the aorta. At this stage of the procedure, the lateral, posterior, and inferior attach-

ments to the kidney are left intact to limit the mobility of the kidney and prevent the possible torsion of the kidney on its vascular pedicle.

The ureter is dissected distally with the gonadal vein and all periureteric tissue beyond the iliac vessels. Endo-GIA vascular stapler or clips are used for rapid division of the ureter and gonadal vessels. Once the kidney dissection is completed, and before dividing the vascular pedicle, the extraction incision has to be prepared temporarily keeping the peritoneum intact to preserve the pneumoperitoneum. Usually a periumbilical incision is made, but lower midline, transverse lower quadrant, and Pfannenstiel's incisions have also been used.[11,31] The use of an entrapment Endo-bag can facilitate the extraction and decrease the incision length.

The endovascular GIA stapler is then used to sequentially divide the renal artery and vein. The kidney is placed in the plastic bag by grasping the perirenal adipose tissue, the peritoneum is opened, and the kidney is finally delivered. The warm ischemia time may be reduced if the kidney is already put into the bag and is ready for extraction before the division of the renal vessels.[30]

### Hand-Assisted Left Laparoscopic Donor Nephrectomy

In hand-assisted LDN, the extraction site is used throughout the operation. A commercial available device (Pneumo-Sleeve) that provides a tight seal at the abdominal wall allows the surgeon's hand to be introduced into the abdomen. The Pneumo-Sleeve is placed through a 7- to 8-cm midline incision either below or centered upon the umbilicus.[32,33] The hand-assisted modification offers the advantage of similarity to open surgery because the surgeon can use his hand to help the kidney exposure and dissection and to control bleeding by finger pressure. The operation otherwise is similar to transperitoneal LDN. The kidney extraction takes place through the Pneumo-Sleeve incision. The hand-assisted technique reduces the operating and warm ischemia time compared with the nonhand-assisted method.[32-34]

### Retroperitoneal Left Laparoscopic Donor Nephrectomy

The retroperitoneal nephrectomy is a well-known and frequently used technique in urological surgery. However, this approach has not been extensively used in living donor nephrectomy.[35,36] The first step of the retroperitoneal approach is the balloon dilation of the retroperitoneal space followed by gas insufflation providing the necessary space to perform the operation, which otherwise is performed with the same laparoscopic instruments. The main feature of the procedure is that the kidney, vasculature, and ureter dissection is performed entirely in the retroperitoneal space. The kidney is extracted through a limited flank incision.

The retroperitoneal approach has the advantage of less interference with the adjusted organs, and by keeping the peritoneum intact, the risk of long-term complications is minimized. The disadvantages are the greatly reduced working space and the fact that the kidney has to be extracted through a flank incision, which is considered less desirable.[37,38]

### Comparison of the Results of the Laparoscopic and Open Approach for Donor Nephrectomy

In comparison with ODN, operating time is significantly longer for laparoscopic procedures **(Table 1)**. The donor complication rates extracted from published comparative studies are presented in **Table 2**. Complications are generally not reported in detail in the literature. When the complication rates are not directly given, we estimate the rate as the number of donors with complications divided by the total number of donors.

When the reported complication rates for the laparoscopic and open methods are equivocal, it is clear that the complications in the laparoscopic approach tend to be more serious. LDN is associated with unanticipated intraoperative incidental vascular injuries and massive bleeding[29] that are not always avoidable (eg, in the case of a stapler misfiring), but hemorrhage leading to multiple blood transfusions is the most common reported serious complication.[11,12,29,39,40] Leventhal et al[27] reported intraoperative vascular injuries in 4 of 80 (5%) LDNs (2 lumbar vein, 1 renal artery, and 1 aortic injury). Flowers et al11 reported injuries in 1 external iliac artery and 2 renal vessels in a series of 70 (4.2%) LDN. Vascular injuries as well as endovascular stapler misfire cases have also been reported by others.[17,18,25] According to Jacobs et al,[17] donor intraoperative vascular injuries developed in 2.8% of the cases, and 10.4% intraoperative complications occurred in their large (n=320) 3-year LDN series. However, up to the present time, no procedure-related death has ever been reported.

**Table 1.**
Mean (±SD If Reported) Operating Time (Min) in Laparoscopic and Open Live Donor Nephrectomy (LDN)

| | Laparoscopic LDN | | Open LDN | |
|---|---|---|---|---|
| Author | No. of Patients | Mean Operative Time (min) | No. of Patients | Mean Operative Time (min) |
| Sasaki et al[18] | 100 | 306.8±54.65 | 36 | 185.36±43.05 |
| Flowers et al[11] | 70 | 226 | 65 | 213 |
| Odland et al[29] | 30 | 183±40 | 30 | 148±33 |
| Leventhal et al[27] | 80 | 276 | 50 | 186 |
| Wolf et al[32] (Hand assisted) | 10 | 215±51 | 40 | 95±21 |

**Table 2.**
Comparative Donor Complication Rates in Reported Controlled Series

| | Laparoscopic LDN | | Open LDN | |
|---|---|---|---|---|
| Author | No. of Donors | Complications % | No. of Donors | Complications % |
| Hiller et al[59] | 9 | 11% | 27 | 15% |
| Sasaki et al[18] | 100 | 5% | 36 | 4% |
| Flowers et al[11] | 70 | 14% | 65 | Not significant |
| Ratner et al[12] | 19 | 5% | 20 | 0% |
| Odland et al[29] | 30 | 20% | 30 | 3% |
| London et al[39] | 12 | 17% | 21 | 5% |
| Leventhal et al[27] | 80 | 11% | 50 | Not reported |
| Wolf et al[32] (Hand assisted) | 10 | 30% | 40 | 35% |

**Table 3** presents the most common causes for conversion to an open procedure. Reported conversion rates to open nephrectomy are 0.9% to 6%.[11,17,18,27,37,41] Uncontrolled bleeding following vascular or spleen injury, complex vascular anatomy, obesity, or other technical difficulties in exposing the kidney are the most common causes.[18,37] Ratner et al[19] found that in LDN the grade of the technical difficulty cannot be preoperatively assessed by the use of anatomical or radiological criteria.

The major and minor complications for laparoscopic and open live donor nephrectomy are presented in **Table 4**. Major complications in LDN occur in 0% to 5% of patients.[27,30,32,42] Historically, the reported incidence of major complications in the ODN is 4.4±3.5%.[43-45] For LDN, all authors agree that major complications occur mainly in early stages of learning, and increasing experience tends to decrease the incidence of major complications.[17,30,32,42]

The estimated average operative blood loss is also experience-related[30] but tends to be slightly less in LDN[18,32] **(Table 5)**. Of note, when reported, the standard deviations of blood loss are remarkably large for both procedures. Odland et al[29] found a significantly higher blood loss in the converted to open operation LDN cases. In our opinion, reported differences of blood loss between the 2 procedures are minimal and without any clinical significance.

The cosmetic result is considered superior with LDN. According to Jacobs et al,[17] the minimum length of the extraction site incision is 7 cm, and it seems that it cannot be further reduced without placing the renal parenchyma in danger of contusion during the extraction process.

In comparison with ODN, postoperative pain after LDN is significantly less, as measured by analgesic require-

**Table 3.**
Causes for Conversion From Laparoscopic to an Open Donor Nephrectomy

| Author | No. of Patients | No. of Converted Cases | Conversion Cause | | |
|---|---|---|---|---|---|
| | | | Vascular Injuries | Spleen Injuries | Obesity or Technical Problems |
| Jacobs et al[17] | 320 | 6 | 4 (1.2%) | 1 (0.3%) | 1 (0.3%) |
| Flowers et al[11] | 70 | 4 | 3 (4.2%) | | 1 (1.4%) |
| Odland et al[29] | 30 | 4 | 3 (10.0%) | | 1 (3.3%) |
| Leventhal et al[27] | 80 | 5 | 3 (3.7%) | | 2 (2.5%) |
| Sasaki et al[18] | 100 | 2 | 1 (1.0%) | | 1 (1.0%) |

**Table 4.**
Reported Complications In Laparoscopic Live Donor Nephrectomy
In Comparison With The Open Nephrectomy Associated Complications

| Laparoscopic LDN | Open LDN |
|---|---|
| **Major Complications** | |
| Aortic injury | Bowel injury |
| Bowel injury | Postoperative hemorrhage |
| Iliac artery injury | Pulmonary embolus |
| Lumbar veins injury | Spleen laceration |
| Mesenteric vein injury | |
| Postoperative hemorrhage | |
| Pulmonary embolus | |
| Renal vessels injury | |
| Spleen laceration | |
| **Minor Complications** | |
| Atelectasis | Deep venous thrombosis |
| Deep venous thrombosis | Flank nerve entrapment |
| Lateral femoral cutaneous nerve injury | Pneumonia |
| Pneumothorax | Pneumothorax |
| Postoperative delayed ileus | Postoperative delayed ileus |
| Postoperative pancreatitis | Postoperative pancreatitis |
| Postoperative small bowel obstruction | Retroperitoneal hematoma |
| Retroperitoneal abscess | Urinary retention |
| Retroperitoneal hematoma | Urinary track infection or Epididymitis |
| Urinary retention | Wound infection |
| Urinary track infection or Epididymitis | |
| Wound infection | |

ments. Oral food intake and ambulation are also reported to occur sooner after LDN.[11,12,17,27,29,32]

Reported series have shown an average hospital stay of 1.8 to 4 days for donors that had a laparoscopic nephrectomy. In all studies,[11,18,27,29,32] the mean hospital stay for patients who underwent LDN was shorter than that of patients who had an open procedure. The average time interval of return to normal activities and work is difficult to estimate precisely, but it has also been reported to be shorter for patients undergoing LDN (2.3 to 3.9 weeks

**Table 5.**
Mean (±SD if Reported) Blood Loss (Ml) in Laparoscopic and Open Live Donor Nephrectomy (LDN)

| | Laparoscopic LDN | | Open LDN | |
|---|---|---|---|---|
| Author | No. of Patients | Estimated Blood Loss (mL) | No. of Patients | Estimated Blood Loss (mL) |
| Sasaki et al[18] | 100 | 130±114.53 | 36 | 150±88.39 |
| Leventhal et al[27] | 80 | 165 | 50 | 174 |
| Odland et al[29] | 30 | 116±22 | 30 | 183±40 |
| Flowers et al[11] | 70 | 122.3 | 65 | 408 |
| Wolf JS et al[32] (Hand assisted) | 10 | 103±69 | 40 | 127±111 |

**Table 6.**
Learning Curve Effects on the Operating Time (Mean ± SD) and Ureteric Complications

| Study | Cases | Operating Time (sec) | No. of Associated Ureteric Complications |
|---|---|---|---|
| Jacobs et al[17] | 0-100 | 226.3±53.7 | 13 |
| University of Maryland | 101-200 | 215.6±42.2 | 5 |
| | 201-320 | 200.0±47.2 | 2 |
| Philosophe et al[47] | 0-130 | Not reported | 20 |
| Ratner et al[28] | 0-33 | | |
| John Hopkins University | 34-70 | Not reported | 1 |
| | 71-110 | Not reported | 8 |
| | | Not reported | 1 |

compared with 4.1 to 7.4 weeks for ODN).[11,12,32,46]

## TRANSPLANTATION RESULTS FOLLOWING LAPAROSCOPIC AND OPEN DONOR NEPHRECTOMY

In renal transplantation, a prolonged warm ischemia time results in acute tubular necrosis and delayed graft functioning. Most of the controlled studies do not mention the ODN warm ischemia time because it is usually less than 2 minutes. In LDN, prolonged warm ischemia time is usually associated with difficulties in the extraction of the graft.[18]

In a controlled study, Odland et al[29] found a significantly longer warm ischemia time in the LDN group (5.0±1.8 min compared with 1.7±1.5 min in the open technique). Jacobs et al[17] presented the 3-year experience at the University of Maryland of 320 LDN and reported a mean warm ischemia time of 2.5 minutes. In 34 of 320 cases, warm ischemia time was more than 4 minutes. The hand-assisted technique has the advantage of offering rapid extraction, reducing the warm ischemia time to only 1.2 minutes to 2.9 minutes.[32,42]

Many authors[12,18,28,29,47] compare the recipient's creatinine levels following LDN and ODN. Ratner et al[28] reported a slightly, but not significantly, better early renal function in patients who received kidneys procured by the open method. All studies[12,18,29,47] agree that no statistically significant difference exists in delayed graft function or in early and later creatinine levels between the recipients of laparoscopically and openly procured kidneys. Long-term graft survival and recipient survival rates were similar for transplants of laparoscopically and openly procured kidneys.[11,25,29,39,47,48]

Posttransplant ureteric complications were initially increased in the recipients of laparoscopically procured renal allografts. The incidence of ureteric complication rates from 3.3% to 11.2% for recipients of laparoscopically procured grafts compared with 3.0% to 6.3% for recipients of openly procured grafts.[28,29,47,49] Furthermore, Philosophe et al[47] found that the risk of ureteric complications requiring operative repair was 3.5 times

higher in the recipients of laparoscopically procured kidneys.

The use of staplers on renal vessels has the disadvantage of shortening the available vessel length. This could mean that an early renal artery branching might be converted into multiple separate vessels that need to be reconstructed before the reimplantation.[50-52] However Cuo et al[49] reported that the presence of multiple renal arteries did not influence the 1-year graft and recipient survival following LDN.

In laparoscopic (as in open) surgery, the learning curve varies with the frequency in which patients are operated on, the type of operation, the volume of the practice, and some parameters related to the individual surgeon. LDN is considered a technically demanding procedure, and experienced surgeons[11] have uniformly reported a rather stiff learning curve. This means that a large number of procedures need to be done before having fewer donor complications and a satisfactory recipient renal function. Operating times and recipient ureteric complication rates according to the experience for the procedure are presented in **Table 6**, and they are good indicators of the difficult learning curve for LDN. Stephen Jacobs, one of the pioneers of LDN at the University of Maryland, discussing the past, present, and future role of LDN,[53] criticized the learning curve difficulties saying, "Unfortunately, the learning curve is awful. It's flat. This means you have to do a lot of these cases before you really feel comfortable. It takes 75 to 100 cases to get to that point, and we've shown in our own series that the complication rate does not taper off until you have passed 100 or so. To get 100 cases in, though, a transplant program needs to be fairly large." The hand-assisted method probably simplifies the procedure, and it is associated with an easier learning curve.[32,34,54]

## THE IMPACT OF LAPAROSCOPIC DONOR NEPHRECTOMY ON LIVE RENAL DONATION

Of the 12 398 kidney transplants performed in 1999 in the United States, three quarters were kidneys from cadaver donors and one third were kidneys from live donors. Unfortunately, the numbers of kidneys from cadaver donors tend to remain relatively stable, but the renal transplant waiting list grows by more than 13% every year. In March 2001, 48 200 patients were waiting for a kidney transplant in the USA. The numbers on the kidney transplant waiting list have almost tripled since 1990.[55] Encouragement of live donation seems to be the best possible solution to the problem. Since the introduction of LDN, some centers have reported an increasing willingness for live kidney donation both from persons related and unrelated to the recipient individuals. The Johns Hopkins and Maryland groups reported an impressive increase in live donor transplants of 50% to 60%.[56,57] An increased donation rate due to the establishment of an LDN program has also been reported by other centers.[18,58]

Hiller et al[59] surveying 61 donors from the John Hopkins University Hospital found that the major donor concerns were the effect of donation on future health, time out of work, ability to return to original activities, and postoperative pain. Kuo et al[58] reported that 47% of the laparoscopically operated donors donated solely because of the potential advantages of the laparoscopic procedure regarding those issues.

However, as yet no clear evidence exists that LDN increases the overall rates of donation. Estimations may have been biased by the advertisement to attract donor-recipient pairs in specialized centers because the University of Maryland and some other centers have established protocols for the preoperative evaluation of potential donors and recipients outside their local area of referral.[60] At the Eighth International Meeting of Laparoendoscopic Surgeons, Jacobs[56] reported that 7% of the patients entered in the University of Maryland laparoscopic donation program were from outside their standard drawing area.

## DISCUSSION

LDN is a promising technique. It seems that it results in less postoperative pain, shorter hospital stay, faster return to normal activities, and better cosmetic results. However, as revealed by the published literature, LDN is still under development and although it has currently reached a rather high security level in the experienced transplant centers, the safety and efficacy of the method in comparison with traditional ODN has not yet been clearly established.[61] Due to the lack of prospective randomized controlled trials, credible comparisons with the open live donor nephrectomy outcomes are generally difficult. In addition, the fact that most of the published comparative studies include small groups of patients suggests that possible significant differences exist that have

not been detected.

Intraoperative infrequent but rather serious complications in LDN must not be underestimated. Sometimes intraoperative incidences such as a stapler misfiring are not avoidable. Recipient ureteric complication rates are by far higher in LDN. However, most of the described complications appear to be related to the learning curve.

The long-term risk of complications either to the donor or recipient has also not yet been evaluated. Until now, the published follow-up times ranged from 6 months to 3 years. Donors' late complications, such as unsuspected vascular injuries or small bowel obstruction due to intraabdominal adhesions, may take several years until they have been properly evaluated.

It seems that to decrease the cost, hospital stay following LDN has been widely reduced; and it cannot be further reduced without jeopardizing patient safety.[56] One of the main limiting factors to early discharge is the return of bowel function.[37] Although a "23-hour stay" protocol for LDN has been introduced by Kuo et al,[62] this extreme reduction in hospitalization does not necessarily mean better patient care.[63] Recently, the Transplant Section of the Royal Australasian College of Surgeons nominated the Australian Safety and Efficacy Register of New International Procedures-Surgical (ASERNIP-S) to review the LDN issue. Following a systematic analysis of the international literature, the ASERNIP-S review group concluded that at present the evidence for LDN is inadequate to make any safety and efficacy recommendation while limited low-level evidence suggests that the laparoscopic approach might be advantageous regarding the donor's hospital stay, convalescence, pain, and resumption of employment. ASERNIP-S recommends, and we clearly agree, that further research such as prospective randomized clinical trials, must be conducted to establish the safety and efficacy of the LDN.[64]

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