

# Meta-Analysis Comparing Risk for Adverse Outcomes After Left Ventricular Assist Device Implantation in Patients With Versus Without Diabetes Mellitus



Noman Lateef<sup>a,\*</sup>, Muhammad Shariq Usman, MBBS<sup>b</sup>, Paolo C. Colombo, MD<sup>c</sup>, Saba Ahmed, MBBS<sup>b</sup>, Muhammad Shahzeb Khan, MD<sup>d</sup>, Safi U. Khan, MD<sup>e</sup>, Arthur R. Garan, MD<sup>c</sup>, Melana Yuzefpolskaya, MD<sup>c</sup>, and Ryan T. Demmer, PhD<sup>f,g</sup>

**Patients with diabetes mellitus (DM) are known to have reduced life expectancy and be at increased risk for multiple morbidities including serious infection. However, published data on DM outcomes after left ventricular assist device (LVAD) implantation are sparse, inconsistent and individual studies are small with limited power. We conducted a systematic review and meta-analysis to compare survival and adverse events post-LVAD in DM versus non-DM (NDM) patients. Medline, Scopus, and Cochrane Central databases were searched for studies comparing outcomes in DM and NDM patients who underwent LVAD implantation for advanced heart failure. Results were reported as random effect risk ratios (RR) with 95% confidence intervals. We identified 5 retrospective cohort studies, at low risk of bias, reporting on 1,351 patients (n = 488 DM). There was increased 30-day mortality (RR 1.57 [1.00, 2.47]; p = 0.05; I<sup>2</sup> = 0%) among DM versus NDM. The DM and NDM groups did not differ significantly in terms of 1-year mortality (RR 1.15 [0.98, 1.35]; p = 0.08; I<sup>2</sup> = 39%), device-related infection (RR 1.05 [0.92, 1.19]; p = 0.88; I<sup>2</sup> = 0%), ischemic stroke (RR 1.29 [0.91, 1.83]; p = 0.69; I<sup>2</sup> = 0%), hemorrhagic stroke (RR 1.10 [0.42, 2.83]; p = 0.85; I<sup>2</sup> = 69%), or bleeding (RR 1.06 [0.80, 1.40]; p = 0.70; I<sup>2</sup> = 27%). After LVAD implantation, patients with DM, versus patients without, have a modestly elevated 30-day mortality rate. However, 1-year mortality and morbidity did not differ. © 2019 Elsevier Inc. All rights reserved. (Am J Cardiol 2019;124:1918–1923)**

The negative impact of DM on heart failure (HF) has been well documented. Despite optimal medical therapy, many HF patients with coexisting DM progress to Stage D HF in which heart transplantation is the gold-standard treatment.<sup>1–3</sup> However, limited allograft resources could mean long waiting periods before transplantation.<sup>4</sup> Furthermore, diabetic end-organ complications and/or severe obesity often exclude these patients from heart transplant candidacy.<sup>5</sup> In such situations, implantation of a left ventricular assist device (LVAD) could continue to provide mechanical circulatory support to these patients as a bridge-to-transplant therapy or a destination therapy. According to the current guidelines by International Society for Heart and Lung Transplantation, LVAD implantation in DM patients is permissible unless the patient has very poor glycemic control or severe end-organ damage (Class IIb; Level of Evidence C).<sup>6</sup> However, this recommendation is based on limited and conflicting data from observational

studies.<sup>7–11</sup> Hence, to address the inconsistencies in the literature, we performed this study by meta-analyzing data from all available observational studies.

## Methods

This meta-analysis was reported in accordance with the Preferred Reporting Items for Systematic review and Meta-Analyses guidelines,<sup>12</sup> and conducted following the American Heart Association guidelines.<sup>13</sup>

MEDLINE, Scopus, and Cochrane Central were searched in February 2018, without any time or language restrictions. Search strategies used in each database are given in [Supplementary Table S1](#). Snowballing from retrieved articles and relevant reviews was performed to ensure no relevant article was missed. All articles were transferred to Endnote X7 (Clarivate Analytics, Pennsylvania), and duplicates were identified and removed. Two reviewers (NL and MSU) independently screened the remaining articles. Articles were initially short-listed on the basis of title and abstract, following which the full-text was read to assess relevance. Any discrepancies between the 2 reviewers were solved by discussion until consensus was reached.

Observational studies or clinical trials reporting outcomes in DM and NDM patients supported with LVADs for HF with any length of follow-up and reporting at least one of the prespecified outcomes were included in our analysis. Editorials, review articles, and single-arm studies were excluded.

<sup>a</sup>Department of Internal Medicine, Creighton University Medical Center, Omaha, Nebraska; <sup>b</sup>Department of Internal Medicine, Dow University of Health Sciences, Karachi, Pakistan; <sup>c</sup>Department of Cardiology, Columbia University, New York, New York; <sup>d</sup>Department of Internal Medicine, John H Stroger Jr Hospital of Cook County, Chicago, Illinois; <sup>e</sup>Department of Internal Medicine, Guthrie Health System/Robert Packer Hospital, Sayre, Pennsylvania; <sup>f</sup>Division of Epidemiology and Community Health, University of Minnesota, Minneapolis, Minnesota; and <sup>g</sup>Department of Epidemiology, Columbia University Irving Medical Center, New York, New York. Manuscript received July 30, 2019; revised manuscript received and accepted September 12, 2019. See page 1923 for disclosure information.

\*Corresponding author: Tel: (531) 444-6031.

E-mail address: [noman.mlateef@gmail.com](mailto:noman.mlateef@gmail.com) (N. Lateef).

All pertinent data were extracted on a standardized data collection form and verified by 2 reviewers (NL and MSU). In case of discrepancies, the original reference article was reviewed. The following study characteristics were extracted: study design, number of patients assigned to each group, participant characteristics, details of the LVAD support, and duration of follow-up. Outcomes of interest included all-cause mortality (30-day and 1-year), thromboembolic stroke/transient ischemic attack, intracerebral hemorrhage/hemorrhagic stroke, device-related infections, and bleeding. In case data on mortality were only given in a graphical form (Kaplan-Meier curves), raw data were digitized and extracted using Plot Digitizer 2.6.8; and risk ratios (RRs) were subsequently calculated.

Risk of bias of the included cohort studies was assessed using the Newcastle-Ottawa scale.<sup>14</sup> This scale is used to assign studies a score out of 9 based on 3 broad criteria: the selection of the study groups; the comparability of the groups; and the ascertainment of the outcome. A study with a score of 7 or more is considered to have a good methodological quality.

Review Manager (Version 5.3. The Cochrane Collaboration; London, United Kingdom) was used to perform the analysis. When analyzing the outcomes, RRs and 95% confidence

intervals were computed and pooled using a random effects model. A random effects model was selected due to observed heterogeneity in study and participant characteristics. Forest plots were generated to visually assess the results of pooling.

Since we used unadjusted outcome measures, we assessed baseline differences between DM and NDM patients included in this study to identify potential confounding factors. To achieve this, we meta-analyzed the baseline demographics and summarized them as weighted mean differences (WMDs) or odds ratios.

Statistical heterogeneity across studies was assessed using Higgins  $I^2$  statistic and a value of  $I^2 = 25\%$  to  $50\%$  was considered mild heterogeneity,  $50\%$  to  $75\%$  as moderate, and  $>75\%$  as severe.<sup>15</sup> A  $p$  value of  $\leq 0.05$  was considered significant in all cases.

## Results

A total of 1,287 articles were retrieved from the initial search. After exclusions, 5 retrospective cohort studies remained for analysis.<sup>7–11</sup> The Preferred Reporting Items for Systematic review and Meta-Analyses flow chart (Figure 1) outlines the literature search process. The 5 selected studies included 1,351 patients ( $n = 488$  DM

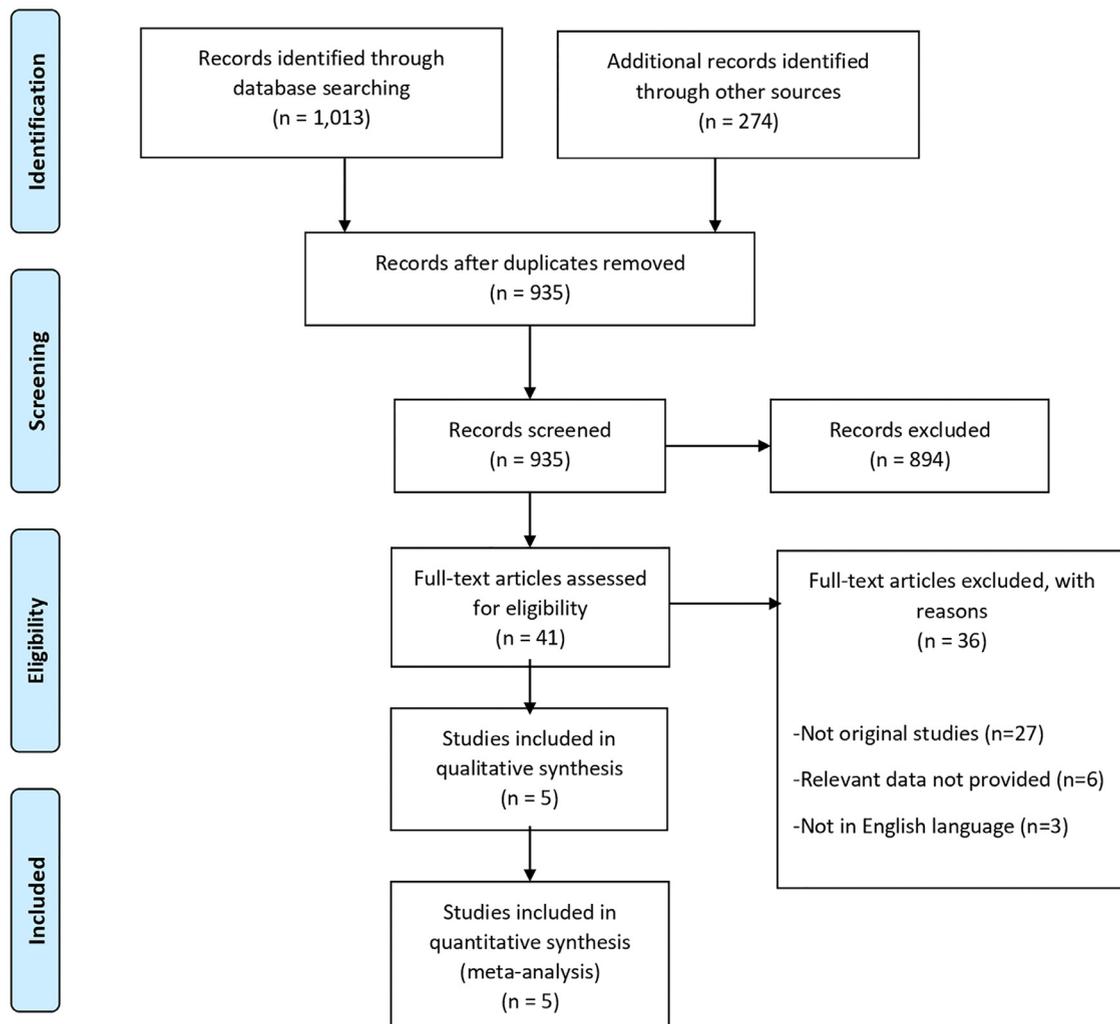


Figure 1. PRISMA flow chart depicting study selection process.

patients, n = 864 NDM patients). Study and baseline characteristics are outlined in Table 1. Table 2 summarizes the differences in key characteristics between DM and NDM patients. In comparison to NDM patients, diabetic patients were significantly older (WMD = 3.27 years; p = 0.01), had a higher body mass index (WMD = 2.44 kg/m<sup>2</sup>; p < 0.001), were more likely to be hypertensive (p < 0.001), and had more often ischemic etiology of HF (p = 0.04). Furthermore, DM patients were more likely to receive LVAD implantation as destination therapy (p < 0.001). Left ventricular ejection fraction was similar between the 2 groups (p = 1.00).

**Mortality (Figure 2):** Patients with DM had a modest but significantly higher risk of 30-day mortality (RR 1.57 [1.00, 2.47]; p = 0.05; I<sup>2</sup> = 0%). However, no significant difference in 1-year mortality (RR 1.15 [0.98, 1.35]; p = 0.08; I<sup>2</sup> = 39%) was noted between the DM and NDM groups.

**Device-related infection (Figure 3):** There were 155/ of 488 (31.8%) events in DM group and 300 of 864 (34.7%) events in NDM group. The risk of device-related infection did not differ significantly between DM and NDM patients (RR 1.05 [0.92, 1.19]; p = 0.88; I<sup>2</sup> = 0%).

**Thromboembolic stroke (Figure 4):** Eight one of 488 (16.6%) DM patients and 174 of 864 (20.1%) NDM patients had thromboembolic stroke but the risk did not vary significantly between the 2 groups (RR 1.29 [0.91, 1.83]; p = 0.69; I<sup>2</sup> = 0%).

**Hemorrhagic stroke (Figure 5):** There was no significant difference in the incidence of hemorrhagic stroke between the 2 groups (RR 1.10 [0.42, 2.83]; p = 0.85; I<sup>2</sup> = 69%) with 12 of 179 (6.7%) and 39 of 331 (11.8%) events occurring in DM and NDM patients, respectively.

**Bleeding (Figure 6):** The incidence of LVAD-associated bleeding was 70 of 228 (30.7%) in DM group and 144 of 483 (29.8%) in NDM group, however, the relative risk was similar between the 2 groups (RR 1.06 [0.80, 1.40]; p = 0.70; I<sup>2</sup> = 27%).

All included studies were of good methodological quality, with a mean Newcastle-Ottawa scale score of 7.2 (Table 1). Publication bias could not be assessed by funnel plot due to low number of included studies (<8).

**Discussion**

To the best of our knowledge, this is the first meta-analysis to compare outcomes in DM and NDM patients after LVAD implantation. The results of this study suggest that DM is associated with an increase in short-term mortality; however, there is no significant difference in long-term mortality. Furthermore, patients with DM are not at increased risk for adverse events such as device infection, thromboembolic stroke, hemorrhagic stroke, or bleeding.

All 5 included studies reported 1-year mortality, and the results of this meta-analysis are consistent with 3 of them, which showed no association between DM and post-LVAD mortality at 1 year.<sup>9-11</sup> For example, the study by Vest et al —comprised of 300 patients—found no link between DM and post-LVAD mortality. In contrast, the most recent and largest study (341 patients) on this topic showed significantly increased 1-year mortality in DM patients, which remained after accounting for 12 confounding factors.<sup>8</sup> The

Table 1  
Study and baseline characteristics

Study	Sample size (DM/NDM)	Device type	Device as DT, DM/NDM	Preoperative HbA1c in DM group	Hypertension, DM/NDM	Ischemic etiology, DM/NDM	Average LVEF, DM/NDM	Average BMI, (kg/m <sup>2</sup> ) DM/NDM	Average age, (years) DM/NDM	Men, % DM/NDM	NOS score
Asleh, 2017	341 (141/210)	HM II (79%) HW HVAD (15%)	70%/59%	7.2%	n/a	56%/40%	18%/18%	31/28	61/62	79%/81%	8
Mohamedali, 2017	288 (122/166)	HM II (85%) HM HVAD (15.3%)	n/r	7.4%	69%/61%	59%/52%	19%/19%	30/27	62/59	82%/75%	7
Vest, 2016	300 (129/171)	HM II (94%) HM HVAD (6%)	37%/39%	7.0%	72%/54%	55%/39%	15%/15%	29/26	59/56	85%/80%	7
Topkara, 2005	201 (49/152)	TH SLVE (100%)	66%/74%	n/a	57%/20%	25%/37%	n/a	30/26	53/49	84%/82%	7
Butler, 2005	222 (57/165)	Novacor (100%)	n/r	n/a	56%/30%	61%/44%	13%/13%	27/26	56/49	86%/89%	7

BMI = body mass index; DM = diabetes mellitus; DT = destination therapy; LVEF = left ventricular ejection fraction; n/a = not available; NDM = nondiabetes mellitus; n/r = not reported.

Table 2

Pooled weighted baseline demographics comparing patients with and without diabetes mellitus (DM)

Baseline Characteristic	DM vs NDM patients	p Value
Age	WMD (95% CI) = 3.27 [0.74, 5.80]	0.01
Males	OR (95% CI) = 1.23 [0.80, 1.90]	0.34
Hypertension	OR (95% CI) = 2.56 [1.52, 4.30]	<0.001
Ischemic heart failure	OR (95% CI) = 1.49 [1.02, 2.18]	0.04
Device as destination therapy	OR (95% CI) = 1.73 [1.28, 2.32]	<0.001
BMI	WMD (95% CI) = 2.44 [1.79, 3.09]	<0.001
LVEF	WMD (95% CI) = 0.00 [-0.87, 0.87]	1

BMI = body mass index; LVEF = left ventricular ejection fraction; OR = odds ratio; WMD = weighted mean difference.

study by Butler et al showed similar results.<sup>7</sup> Three studies reported 30-day post-LVAD mortality,<sup>7-9</sup> and all leaned toward a higher mortality in the DM group, but did not reach statistical significance. A similar result of borderline significance was seen upon meta-analysis of these studies.

DM is associated with an increased risk of certain infections, including soft tissue infections, which are relevant to patients who underwent LVAD implantation.<sup>16</sup> This is due to an impaired immune response in these patients.<sup>17,18</sup> However, our study shows no increase in the risk of device-related infections in diabetic patients. In 2014, Boyle et al reported DM as an independent risk factor for ischemic stroke in 956 patients on LVAD support.<sup>19</sup> However, a similar effect was not seen upon meta-analysis of the 4 studies reporting this outcome. Similarly, this study showed no association between DM and hemorrhagic stroke (reported by 3 studies) or bleeding (reported by 3 studies) after LVAD implantation. These results concur with those obtained by Boyle et al.<sup>19</sup>

It is important to consider that the DM patients in this study were significantly older and had a higher prevalence of hypertension and ischemic HF at baseline, all of which are independent risk factors for adverse events or mortality in patients who underwent LVAD implantation.<sup>7,20</sup> Despite the considerable burden of risk factors within the DM

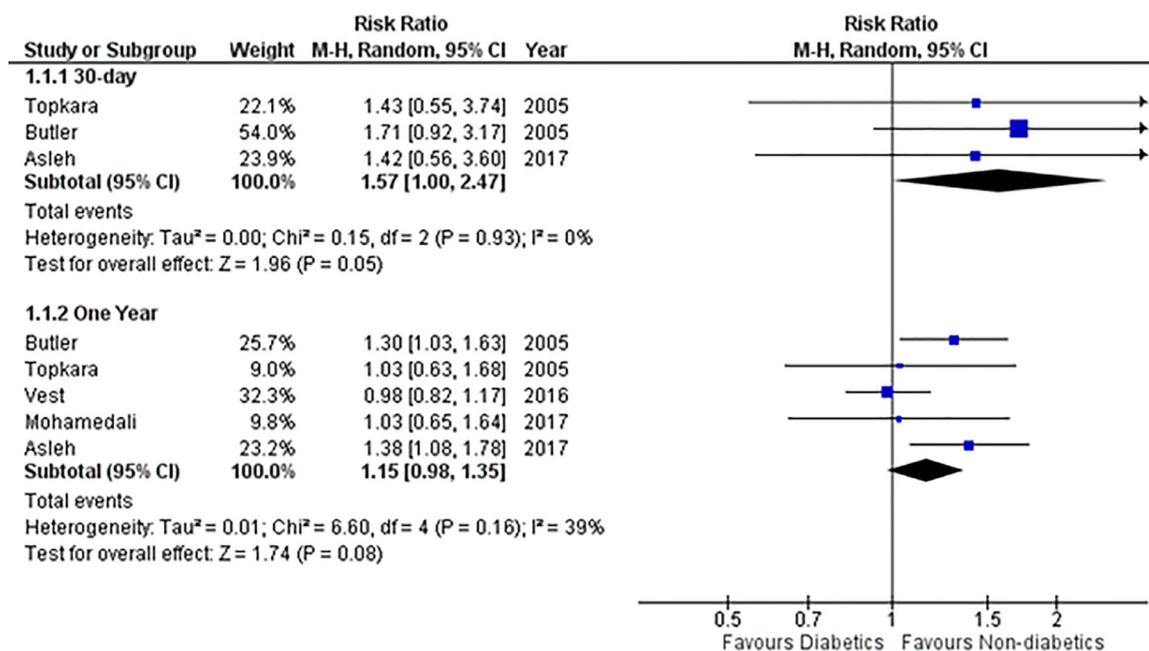


Figure 2. Forest plot comparing 30-day and 1-year mortality between DM and NDM patients. Squares represent the risk ratio of the individual studies; horizontal lines represent the 95% confidence intervals (CI) of the risk ratio. The size of the squares reflects the weight that the corresponding study contributes in the meta-analysis. The diamonds represent the pooled risk ratio or the overall effect. DM = diabetes mellitus; NDM = nondiabetes mellitus.

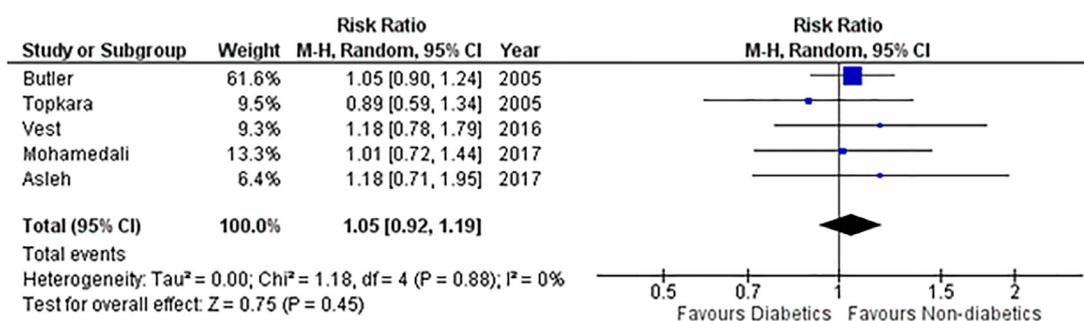


Figure 3. Forest plot comparing the risk of device-related infection between DM and NDM patients. Other annotations as in Figure 2.

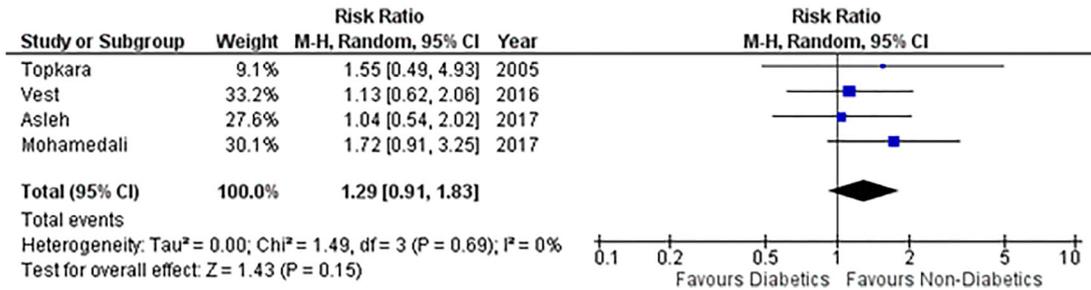


Figure 4. Forest plot comparing the risk of thromboembolic stroke between DM and NDM patients. Other annotations as in Figure 2.

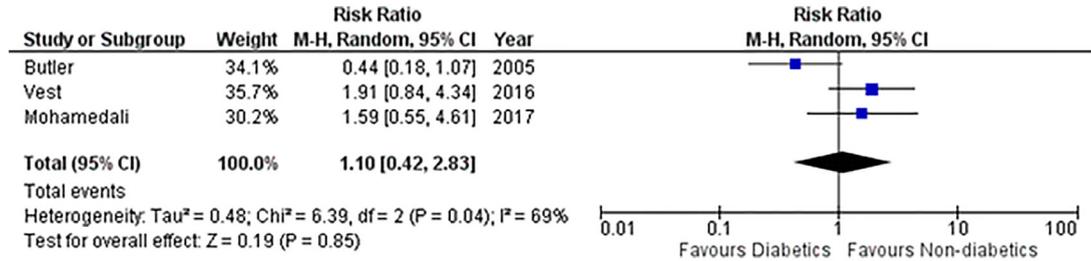


Figure 5. Forest plot comparing the risk of hemorrhagic stroke between DM and NDM patients. Other annotations as in Figure 2.

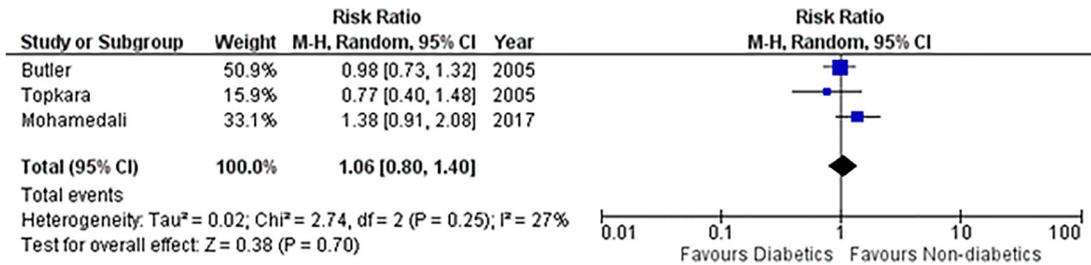


Figure 6. Forest plot comparing the risk of bleeding between DM and NDM patients. Other annotations as in Figure 2.

group, the DM status did not increase the long-term risk of mortality or adverse outcomes during LVAD support.

A possible explanation for this could be the presence of certain protective factors which may benefit diabetics such as higher body mass index. In HF, obese patients have shown to have more favorable outcomes than nonobese ones, despite obesity being a causal factor for HF.<sup>21</sup> This “obesity paradox” has also been demonstrated in a specific population of HF patients who underwent LVAD implantation.<sup>22</sup> Although we do not believe that obesity is truly protective of mortality in HF, it is likely a phenotypic marker indicating better prognosis, one of the possible explanations being the inclusion of cachexic HF patients in the comparison cohorts. Further, there is robust evidence suggesting improved glycemic control after LVAD implantation.<sup>8,10,23,24</sup> In fact, a 2014 study showed that average HbA1c levels can drop up to 2.3%, and persist for at least 1-year post implant.<sup>24</sup> This likely results from the favorable metabolic effects of improved hemodynamics in HF patients who have received an LVAD. Mechanical support increases perfusion and decreases congestion of the pancreas, and concurrently improves systemic circulation of insulin.<sup>25</sup>

This study has important clinical implications as it presents a strong case to proceed with LVAD implantation in DM patients who otherwise meet mechanical circulatory

support criteria in accordance with current guideline.<sup>6</sup> However, the latter also caution against LVAD placement in diabetics with poor glycemic control. Due to insufficient data, we were unable to study the association between baseline glycemic levels and post-LVAD outcomes. Higher glucose levels at baseline have been shown to be associated with increased adverse outcomes in patients who underwent coronary artery bypass graft surgery.<sup>26</sup> However, there exists a dearth of literature in this area for patients who underwent LVAD implantation. Thus, existing evidence does not support the assertion that poor glycemic control reduces survival in LVAD patients with DM.<sup>10</sup>

Certain limitations are applicable to this study. First, use of unadjusted values from observational studies is likely to introduce substantial confounding into meta-analyses. Second, although mortality was stratified by time, all other outcomes were considered over the entire study period. Hence, variation in follow-up times between studies could have led to some bias in these outcomes. Third, some outcomes were only reported by 3 studies, reducing the power of meta-analysis.

In conclusion, patients with DM, versus patients without, have a modestly elevated 30-day mortality rate after LVAD implantation. However, 1-year mortality rates, device-related

infection, and bleeding rates were not different. In essence, LVAD implantation in DM patients appears to be safe and effective. However, our results represent an overall cohort of DM patients and related factors such as type, severity of DM, and diabetic end-organ complications could not be accounted for. Future studies must investigate whether these factors impact outcomes in DM patients after LVAD implantation.

## Disclosures

The authors have no conflicts of interest to disclose.

## Supplementary materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.amjcard.2019.09.021>.

- Ho KK, Anderson M, Kannel WB, Grossman W, Levy D. Survival after the onset of congestive heart failure in Framingham Heart Study subjects. *Circulation* 1993;88:107–115. <https://doi.org/10.1161/01.cir.88.1.107>.
- Dei Cas A, Khan SS, Butler J, Mentz RJ, Bonow RO, Avogaro A, Tschoepe D, Doehner W, Greene SJ, Senni M, Gheorghide M, Fonarow GC. Impact of diabetes on epidemiology, treatment, and outcomes of patients with heart failure. *JACC Heart Fail* 2015;3:136–145. <https://doi.org/10.1016/j.jchf.2014.08.004>.
- Domanski M, Krause-Steinrauf H, Deedwania P, Follmann D, Ghali JK, Gilbert E, Haffner S, Katz R, Lindenfeld J, Lowes BD, Martin W, McGrew F, Bristow MR, BEST Investigators. The effect of diabetes on outcomes of patients with advanced heart failure in the BEST trial. *J Am Coll Cardiol* 2003;42:914–922. [https://doi.org/10.1016/s0735-1097\(03\)00856-8](https://doi.org/10.1016/s0735-1097(03)00856-8).
- Gridelli B, Remmuzzi G. Strategies for making more organs available for transplantation. *N Engl J Med* 2000;343:404–410. <https://doi.org/10.1056/NEJM200008103430606>.
- Mokdad AH, Bowman BA, Ford ES, Vinicor F, Marks JS, Koplan JP. The continuing epidemics of obesity and diabetes in the United States. *JAMA* 2001;286:1195–1200. <https://doi.org/10.1001/jama.286.10.1195>.
- Feldman D, Pamboukian SV, Teuteberg JJ, Birks E, Lietz K, Moore SA, Morgan JA, Arabia F, Bauman ME, Buchholz HW, Deng M, Dickstein ML, El-Banayasy A, Elliot T, Goldstein DJ, Grady KL, Jones K, Hryniewicz K, John R, Kaan A, Kusne S, Loebe M, Massicotte MP, Moazami N, Mohacsi P, Mooney M, Nelson T, Pagani F, Perry W, Potapov EV, Eduardo Rame J, Russell SD, Sorensen EN, Sun B, Strueber M, Mangi AA, Petty MG, Rogers J, International Society for Heart and Lung Transplantation. The 2013 International Society for Heart and Lung Transplantation Guidelines for mechanical circulatory support: executive summary. *J Heart Lung Transplant* 2013;32:157–187. <https://doi.org/10.1016/j.healun.2012.09.013>.
- Butler J, Howser R, Portner PM, Pierson RN 3rd. Diabetes and outcomes after left ventricular assist device placement. *J Card Fail* 2005;11:510–515. <https://doi.org/10.1016/j.cardfail.2005.05.003>.
- Asleh R, Briasoulis A, Schettle SD, Tchanchaleishvili V, Pereira NL, Edwards BS, Clavell AL, Maltais S, Joyce DL, Joyce LD, Daly RC, Kushwaha SS, Stulak JM. Impact of diabetes mellitus on outcomes in patients supported with left ventricular assist devices: a single institutional 9-year experience. *Circ Heart Fail* 2017;10:e004213. <https://doi.org/10.1161/CIRCHEARTFAILURE.117.004213>.
- Topkara VK, Dang NC, Martens TP, Cheema FH, Liu JF, Liang LM, Cheema AF, Barili F, Oz MC, Naka Y. Effect of diabetes on short- and long-term outcomes after left ventricular assist device implantation. *J Heart Lung Transplant* 2005;24:2048–2053. <https://doi.org/10.1016/j.healun.2005.06.021>.
- Vest AR, Mistak SM, Hachamovitch R, Mountis MM, Moazami N, Young JB. Outcomes for patients with diabetes after continuous-flow left ventricular assist device implantation. *J Card Fail* 2016;22:789–796. <https://doi.org/10.1016/j.cardfail.2016.02.010>.
- Mohamedali B, Yost G, Bhat G. Is diabetes mellitus a risk factor for poor outcomes after left ventricular assist device placement? *Tex Heart Inst J* 2017;44:115–119. <https://doi.org/10.14503/THIJ-15-5698>.
- Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, Clarke M, Devereaux PJ, Kleijnen J, Moher D. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ* 2009;339:b2700. <https://doi.org/10.1136/bmj.b2700>.
- Rao G, Lopez-Jimenez F, Boyd J, D'Amico F, Durant NH, Hlatky MA, Howard G, Kirley K, Masi C, Powell-Wiley TM, Solomonides AE, West CP, Wessel J. American Heart Association Council on Lifestyle and Cardiometabolic Health. Council on Cardiovascular and Stroke Nursing. Council on Cardiovascular Surgery and Anesthesia. Council on Clinical Cardiology. Council on Functional Genomics and Translational Biology. Stroke Council. Methodological standards for meta-analyses and qualitative systematic reviews of cardiac prevention and treatment studies: a scientific statement from the American Heart Association. *Circulation* 2017;136:e172–e194. <https://doi.org/10.1161/CIR.0000000000000523>.
- Wells GA, Shea B, O'Connell D, Peterson J, Welch V, Losos M, Tugwell P. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomized studies in meta-analyses. 2009. [[http://www.ohri.ca/programs/clinical\\_epidemiology/oxford.asp](http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp)]
- Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003;327:557–560. <https://doi.org/10.1136/bmj.327.7414.557>.
- Joshi N, Caputo GM, Weitekamp MR, Karchmer AW. Infections in patients with diabetes mellitus. *N Engl J Med* 1999;341:1906–1912. <https://doi.org/10.1056/NEJM199912163412507>.
- Delamaire M, Maugeudre D, Moreno M, Le Goff MC, Allanic H, Genetet B. Impaired leucocyte functions in diabetic patients. *Diabet Med* 1997;14:29–34. [10.1002/(SICI)1096-9136(199701)14:1<29::AID-DIA300>3.0.CO;2-V].
- McMahon MM, Bistrian BR. Host defenses and susceptibility to infection in patients with diabetes mellitus. *Infect Dis Clin North Am* 1995;9:1–9.
- Boyle AJ, Jorde UP, Sun B, Park SJ, Milano CA, Frazier OH, et al. Pre-operative risk factors of bleeding and stroke during left ventricular assist device support: an analysis of more than 900 heartmate II outpatients. *J Am Coll Cardiol* 2014;63:880–888. <https://doi.org/10.1016/j.jacc.2013.08.1656>.
- Saeed O, Jermyn R, Kargoli F, Madan S, Mannem S, Gunda S, Nucci C, Farooqui S, Hassan S, Al Mclarty, Bloom M, Zolty R, Shin J, D'Alessandro D, Goldstein DJ, Patel SR. Blood pressure and adverse events during continuous flow left ventricular assist device support. *Circ Heart Fail* 2015;8:551–556. <https://doi.org/10.1161/CIRCHEARTFAILURE.114.002000>.
- Horwich TB, Fonarow GC, Hamilton MA, MacLellan WR, Woo MA, Tillisch JH. The relationship between obesity and mortality in patients with heart failure. *J Am Coll Cardiol* 2001;38:789–795. [https://doi.org/10.1016/s0735-1097\(01\)01448-6](https://doi.org/10.1016/s0735-1097(01)01448-6).
- Butler J, Howser R, Portner P, Pierson RN III. Body mass index and outcomes after left ventricular assist device placement. *J Thorac Surg* 2005;79:66–73. <https://doi.org/10.1016/j.athoracsur.2004.06.047>.
- Khan MS, Yuzefpolskaya M, Memon MM, Usman MS, Yamani N, Garan AR, Demmer RT, Colombo PC. Outcomes associated with obesity in patients undergoing left ventricular assist device implantation: a systematic review and meta-analysis. *ASAIO J* 2019. <https://doi.org/10.1097/MAT.0000000000001019>.
- Guglin M, Maguire K, Missimer T, Faber C, Caldeira C. Improvement in blood glucose control in patients with diabetes after implantation of left ventricular assist devices. *ASAIO J* 2014;60:290–293. <https://doi.org/10.1097/MAT.0000000000000064>.
- Mohamedali B, Yost G, Bhat G. Mechanical circulatory support improves diabetic control in patients with advanced heart failure. *Eur J Heart Fail* 2014;16:1120–1124. <https://doi.org/10.1002/ejhf.166>.
- Lazar HL, Chipkin SR, Fitzgerald CA, Bao Y, Cabral H, Apstein CS. Tight glycemic control in diabetic coronary artery bypass graft patients improves perioperative outcomes and decreases recurrent ischemic events. *Circulation* 2004;109:1497–1502. <https://doi.org/10.1161/01.CIR.0000121747.71054.79>.