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# Getting transpose-free Lanczos-type iterative methods to work inside of Newton-Krylov methods for nonlinear systems

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Newton-Krylov methods for nonlinear PDEs employ Krylov-subspace solvers for the linear systems generated at each Newton iteration. The matrix-vector products required by the linear solver are frequently obtained via finite-difference approximations to directional derivatives, without ever generating the matrix. The common experience is that these Jacobian-free methods only work for computationally expensive linear solvers, such as GMRES, but fail for Lanczos-based iterations, such as TFQMR. In this talk, we discuss the reasons for the failure of Lanczos-based iterations, propose remedies, and present the results of some numerical experiments.