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We show that in prime dimensions not equal to three, each group covariant symmetric informationally complete positive operator valued measure (SIC~POVM) is covariant with respect to a unique Heisenberg--Weyl (HW) group. Moreover, the symmetry group of the SIC~POVM is a subgroup of the Clifford group. Hence, two SIC~POVMs covariant with respect to the HW group are unitarily or antiunitarily equivalent if and only if they are on the same orbit of the extended Clifford group. In dimension three, each group covariant SIC~POVM may be covariant with respect to three or nine HW groups, and the symmetry group of the SIC~POVM is a subgroup of at least one of the Clifford groups of these HW groups respectively. There may exist two or three orbits of equivalent SIC~POVMs for each group covariant SIC~POVM, depending on the order of its symmetry group. We then establish a complete equivalence relation among group covariant SIC~POVMs in dimension three, and classify inequivalent ones according to the geometric phases associated with fiducial vectors. Finally, we uncover additional SIC~POVMs by regrouping of the fiducial vectors from different SIC~POVMs which may or may not be on the same orbit of the extended Clifford group.