Human iPSC line PG64SV.2 was generated from fibroblasts of a patient with a defect of intergenomic communication. This patient harbored a homozygous mutation (c.2243G>C; p.Trp748Ser) in the gene encoding the catalytic subunit of the mitochondrial DNA polymerase gamma gene (POLG). Reprogramming factors Oct3/4, Sox2, Klf4, and cMyc were delivered using a non integrative methodology that involves the use of Sendai virus. © 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Fig. 1. Molecular and functional characterization of the PG64SV.2 iPSC line. 1A. Electropherograms showing the c.2243G > C mutation in the patient’s fibroblasts and in the PG64SV.2 line. 1B. Typical ES-like colony morphology of the PG64SV.2 iPSC line. 1C. Positive phosphatase alkaline staining. 1D. Confirmation by RT-PCR of the exogenous reprogramming factors and sendai virus vector silencing. 1E. QPCR showing the expression of the pluripotency associated markers NANOG, OCT4, SOX2, KLF4, CRIPTO and REX1. 1F. Immunofluorescence analysis showing expression of typical pluripotent ES cell markers such as the transcription factors Oct4, Nanog, Sox2 and the surface markers SSEA3, SSEA4, Tra1-60 and Tra1-81; scale bars: 300 μm. 1G. Bisulfite pyrosequencing of the OCT4 and NANOG promoters. The promoters of the transcription factors, OCT4 and NANOG were almost demethylated in the generated iPSC line. 1H. Karyotype analysis. PG64SV.2 has a normal karyotype (46, XX). 1I. DNA fingerprinting analysis showing that PG64SV.2 comes from the patient’s fibroblasts. 1J. Embryoid body based in vitro differentiation assays. PG64SV.2 differentiates into all three germ layers, demonstrated by positive AFP endoderm staining (l), positive Tuj1 ectoderm staining and positive SMA mesoderm staining.
was derived from the patient’s fibroblasts (Fig. 1). Finally, the capacity of the generated iPSC line to differentiate into the three germ layers (endoderm, mesoderm and ectoderm) was tested in vitro using an embryoid body based assay (Fig. 1).

3. Materials and methods

3.1. Non-integrative reprogramming of mutant POLG fibroblasts into iPSC

All the experimental protocols included in the present study were approved by the Institutional Ethical Committee of the Autonoma University of Madrid according to Spanish and European Union legislation. Human fibroblasts from a patient presenting with a defect of intergenic communication caused by a homozygous mutation in the POLG gene (c.2243G-C; p.Trp748Ser) were obtained from EuroBiobank (http://www.eurobiobank.org/en/services/services.htm). These fibroblasts were reprogrammed using the CytoTune-iPSC 2.0 Sendai reprogramming kit following the instructions of the manufacturer. After eight passages of the iPSC line, silencing of the exogenous reprogramming factors genes and sendai virus genome was confirmed by RT-PCR following the manufacturer’s instructions. PG64SV.2 was maintained and expanded both on feeder layers and on feeder-free layers. In the first case, irradiated human fibroblast feeders with ES medium containing: Knockout DMEM (Life technologies), Knockout serum replacement 20%, (Life technologies), MEM non-essential amino acids solution 1X (Life technologies), GlutaMAX 1X (Life technologies), β- mercaptoethanol (100 μM), penicillin/streptomycin 1X (Life technologies) and bFGF (4 ng/ml) [Miltenyi Biotec] were used. Subsequently, PG64SV.2 was adapted and cultured in feeder-free conditions on matrigel (354,277, Corning) with mTeSR1 medium (StemCell) following the recommendations of the manufacturer. For the propagation of the line, both enzymatic (disperse, collagenase IV and accumax) and mechanical procedures have been used.

3.2. Phosphatase alkaline analysis

The iPSC line PG64SV.2 was seeded on a feeder layer plate. After six days direct phosphatase alkaline activity was determined using the phosphatase alkaline blue membrane substrate solution kit (Sigma, AB0300) following the instructions of the manufacturer.

3.3. Mutation analysis

Total DNA from the patient’s fibroblasts and iPSCs was extracted using a standard phenol-chloroform protocol. Subsequently, amplification by PCR of the of POLG gene region containing the c.2243G-C mutation (exon 13) was carried out using the following primers: POLG-13F: 5′-ATGGCCCTTGCTGAATGCAG-3′ and POLG-13R: 5′-TGGGCTTTCAGAGAAATGAG-3′. Following PCR amplification, direct sequencing of amplicons was performed on both strands in an ABI 3730 sequencer (Applied Biosystems; Foster City, CA) using a dye terminator cycle sequencing kit (Applera, Rockville, MD).

3.4. QPCR analyses

Total mRNA was isolated using TRIZOL and 1 μg was used to synthesize cDNA using the Quantitect reverse transcription cDNA synthesis kit. One microliter of the reaction was used to quantify by qPCR the expression of the endogenous pluripotency associated genes (OCT4, SOX2, KLF4, NANOG, CRIPTO and REX1). Primer sequences were described by Aasen et al., 2008. All the expression values were normalized to the GAPDH housekeeping gene. Plots are representative of at least three independent experiments.

3.5. Bisulfite pyrosequencing

Bisulfite modification of genomic DNA was performed with the EZ DNA Methylation-Gold kit (Zymo Research) following the manufacturer’s instructions. The set of primers for PCR amplification and sequencing of NANOG and OCT4 were designed using the software PyroMark Assay Design (version 2.0.01.15; Qiagen): Forward-NANOG (5′-TAT TGG TAT AGG GTG GGG TTA-3′), Reverse-NANOG (5′-[Btg]- CCC AAC AAC AAA TAC TTC TAA ATT CAC-3′), and sequencing primer S-NANOG (5′-ATA GGG GTG GTT TAT-3′); Forward-OCT4_prox (5′-GGG GTT AGA GGT TAA GTG TAG TG-3′), Reverse-OCT4_prox (5′-[Btg]- ACC CCC CTA ACC CAT CAC-3′), and sequencing primer S-OCT4_prox (5′-GGG GTT GAG TAG TTT-3′); Forward-OCT4_dist (5′-TTT TTG TGG GTG AGT TGT ATT GA-3′), Reverse-OCT4_dist (5′-[Btg]- AAA CTA CTC ACC CCC TCT CT-3′), and sequencing primer S-OCT4_dist (5′-ATT TGT AGG GGT GTT GTG GA-3′). PCR was performed with primers biotinylated to convert the PCR product to single-stranded DNA templates, using the Vacuum Prep Tool. After PCR amplification, pyrosequencing reactions and methylation quantification were performed using PyroMark Q24 reagents, equipment and software (version 2.0.6; Qiagen), according to the manufacturer’s instructions.

3.6. Karyotype analysis

Karyotype analyses of the iPSC line were carried out using cells with more than twenty culture passages. These cells were processed using standard cytogenetic techniques. Briefly, cells were treated with 10 μg/ml of Colcemid (Gibco) for 90 min at 37 °C, trypsinized, treated with 0.075 M hypotonic KCl solution, and fixed with Carnoy’s fixative. Cells were then dropped on a microscope glass slide and dried. Metaphase cells were G banded using Wright staining. At least 20 metaphases were karyotyped.

3.7. Immunofluorescence analysis

Cells were grown on 0.1% gelatin-coated P35 culture plates (81,156, Ibidi) and fixed with 4% paraformaldehyde. The following antibodies for the staining were used: TRA-1–60 (Millipore; MAB4360; 1:150); TRA-1–81 (Millipore; MAB4381; 1:150); SOX2. (Thermo Scientific; PAI16968; 1:100); NANOG (Ro&D Systems; AF1997; 1:25); SSEA-4 (Millipore; MAB4304; 1:10); SSEA-3 (Millipore; MAB4303; 1:10); OCT4 (Santa Cruz Biotechnology; Sc-5279; 1:100); neuron-specific class III betatubulin (TuJ1) (Sigma, T8660, 1:300), α-fetoprotein (AFP) (Sigma, WH0000174M1, 1:300), smooth muscle alpha actin (SMA) (Sigma, A2547, 1:400). Secondary antibodies used were all from the Alexa Fluor Series from Jackson ImmunoResearch (all 1:500). Images were taken using a Zeiss confocal microscope.

3.8. In vitro differentiation assay

The in vitro pluripotency capacity of the iPSC line was tested by spontaneous embryoid body differentiation. For this purpose, iPSCs from a P100 plate with 80% of confluency were dissociated into a single cell suspension with accumax (SCR006,Millipore) and resuspended in 12 ml of mTeSR1 medium (StemCell). Embryoid body formation was induced by seeding 120 μl of the iPSC suspension in each well of 96-well v-bottom low attachment plates and centrifuging the plates at 800 g for 10 min to aggregate the cells. After 2–3 days the embryoid bodies were transferred to an untreated P60 culture plate for 2–4 days. Subsequently, the embryoid bodies were transferred to 0.1% gelatin-coated P35 culture plates (81,156, Ibidi) and cultured in differentiation medium (DMEM F12 supplemented with 20% fetal bovine serum, 2 mM glutamine, 0.1 mM β-mercaptopoethanol, 1X non essential amino acids and 1X penicillin–streptomycin, all from Invitrogen) for 2–3 weeks to allow spontaneous endoderm formation. For mesoderm differentiation, iPSCs were maintained for 2–3 weeks in differentiation
medium supplemented with 100 μM ascorbic acid (A4403, Sigma-Aldrich). For ectoderm differentiation, embryoid bodies were transferred to matrigel coated P35 culture plates and cultured in a special differentiation medium containing (50% DMEM F12, 50% neurobasal medium, 1X GlutaMAX, 1X penicillin–streptomycin, non-essential amino acids, 0.1 mM 2-mercaptoethanol, 1X N2 supplement and 1X B27 supplement, all from Invitrogen). In all the cases, the medium was changed every other day.

3.9. DNA fingerprinting analysis

For DNA fingerprinting analysis, highly polymorphic regions containing short tandem repeated sequences of DNA have been evaluated. For this purpose, the following markers (D13S317, D7S820, VWA, D8S1179, D21S11, D19S433, D2S1338 and amelogenin for sex determination) have been amplified by PCR and analyzed by ABI PRISM 3100 Genetic analyzer and Peak Scanner v3.5 (Applied Biosystems). Primer sequences and PCR conditions are available upon request.

Author disclosure statement

There are no competing financial interests in this study.

Acknowledgments

We thank Muscle Tissue Culture Collection (MTCC) for providing the sample. The Muscle Tissue Culture Collection is part of the German network on muscular dystrophies (MD-NET, service structure S1, 01GM0601) and the German network for mitochondrial disorders (mito-NET, project D2, 01GM0862) funded by the German ministry of education and research (BMBF, Bonn, Germany). The Muscle Tissue Culture Collection is a partner of EuroBioBank (www.eurobiobank.org) and TREAT-NMD (www.treat-nmd.eu). This work was supported by grants from the “Centro de Investigación Biomédica en Red en enfermedades raras” (CIBERER) (Grant 13-717/132.05 to RG), the “Instituto de Salud Carlos III” [Fondo de Investigación Sanitaria and Regional development fund (ERDF/FEDER) funds PI10/0705 and PI13/00556 to RG and PI15/00484 to MEG], “Comunidad Autónoma de Madrid” (Grant number S2010/BMD-2402 to RG); TG receives grant support from the Universidad Autónoma de Madrid (FPI-UAM) and FZD from the Ministerio de Educación, Cultura y Deporte (Grant FPU13/00544). MEG is staff scientist at the “Centro de Investigación Biomédica en Red en Enfermedades Raras” (CIBERER).

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