Supplementary information

1. Supplementary Notes

Supplementary Note 1. TEER and capacitance equations.

From the equivalent circuit model of Figure 1H, the impedance Z_{14}, Z_{23}, Z_{12} and Z_{34}, between electrode pairs 1-4, 2-3, 1-4 and 2-3 can be calculated by the following equations (4), (5), (6) and (7), respectively.

$$Z_{1-4} = Z_1 + R_a + \frac{R}{1+\omega^2 C^2 R^2} - j\frac{\omega^2 C R^2}{1+\omega^2 C^2 R^2} + R_b + Z_4 \quad (4)$$

$$Z_{2-3} = Z_2 + R_a + \frac{R}{1+\omega^2 C^2 R^2} - j\frac{\omega^2 C R^2}{1+\omega^2 C^2 R^2} + R_b + Z_3 \quad (5)$$

$$Z_{1-2} = Z_1 + Z_2 \quad (6)$$

$$Z_{3-4} = Z_3 + Z_4 \quad (7)$$

in which f is the frequency. $Z_1 = Z_2 = Z_3 = Z_4$ holds from the symmetry of the four electrodes. The equations (4), (5), (6) and (7) are substituted into the equation (1), we obtain

$$Z = R_a + R_b + \frac{R}{1+\omega^2 C^2 R^2} - j\frac{\omega^2 C R^2}{1+\omega^2 C^2 R^2} \quad (8).$$

If we divide the equation (8) into the real and imaginary parts,

$$Re\{Z\} = R_a + R_b + \frac{R}{1+\omega^2 C^2 R^2} \quad (9)$$

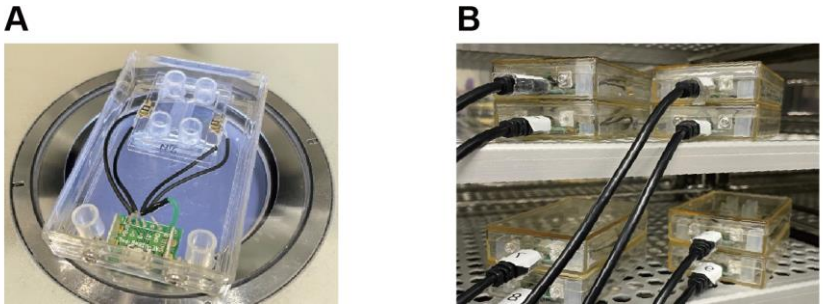
$$Im\{Z\} = -\frac{\omega^2 C R^2}{1+\omega^2 C^2 R^2} \quad (10).$$

From the above equations (9) and (10), we obtain

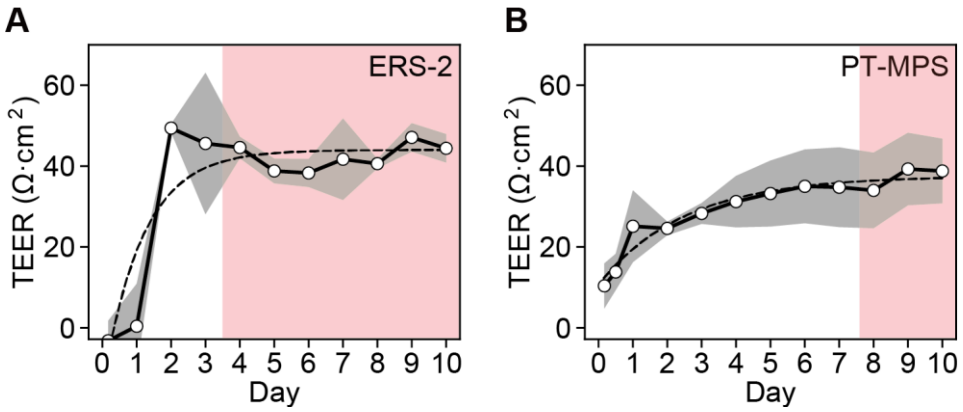
$$R = \frac{(Re\{Z\} - (R_a + R_b))^2 + Im\{Z\}^2}{Re\{Z\} - (R_a + R_b)} \quad (2)$$

$$C = -\frac{\omega \cdot Im\{Z\}}{\left(Re\{Z\} - (R_a + R_b)\right)^2 + Im\{Z\}^2} \quad (3).$$

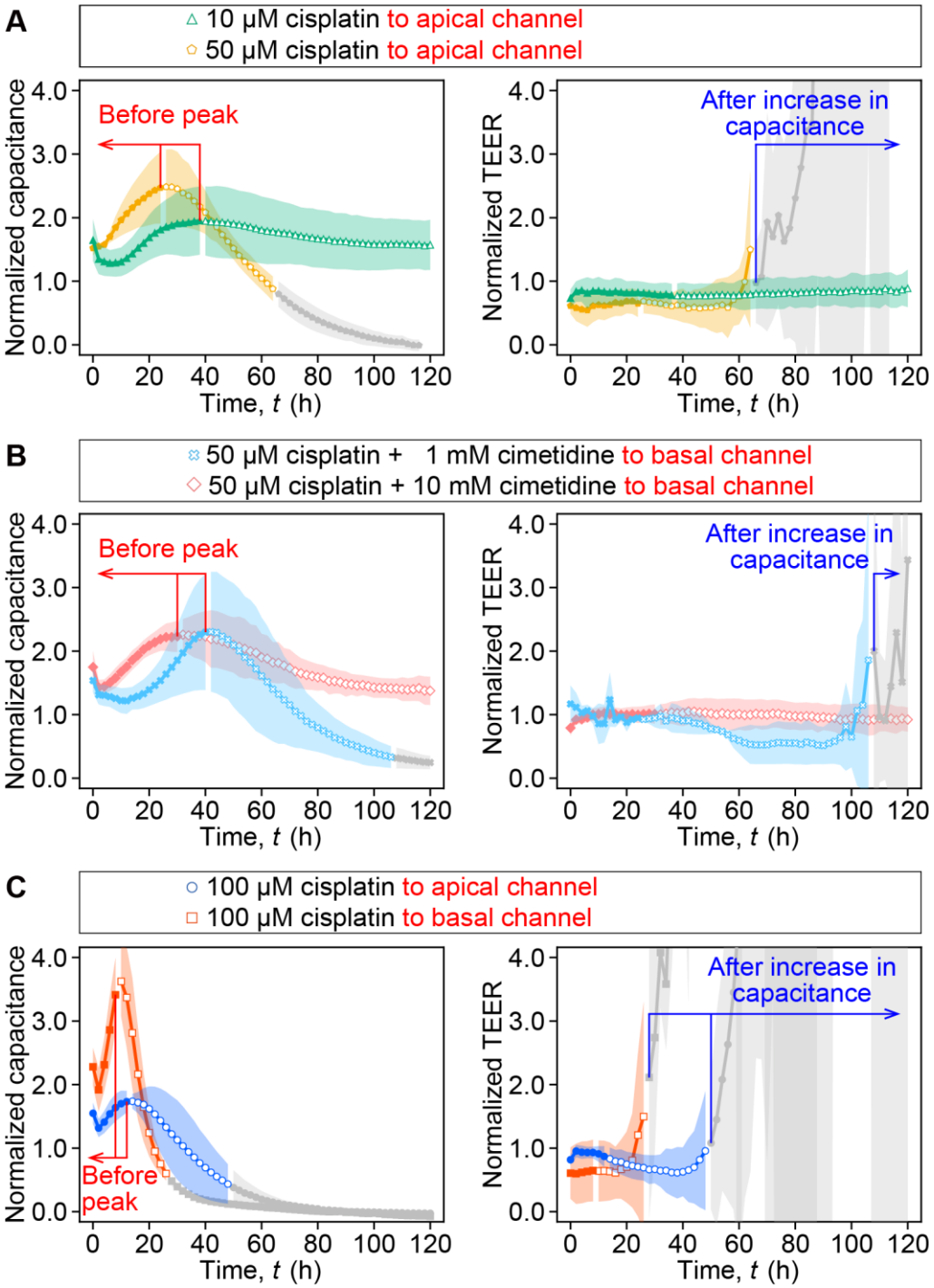
2. Supplementary Figures



Supplementary Figure 1. Photographs of our MPS and TEER measurement setup. A. The devices were mounted on a polystyrene case and were connected to LCR meters USB connectors, allowing measurements inside an incubator. B. Simultaneous measurements of up to 8 devices made from multiple devices inside the incubator by connecting the cable from the outside via a custom-made unit of relay circuits.

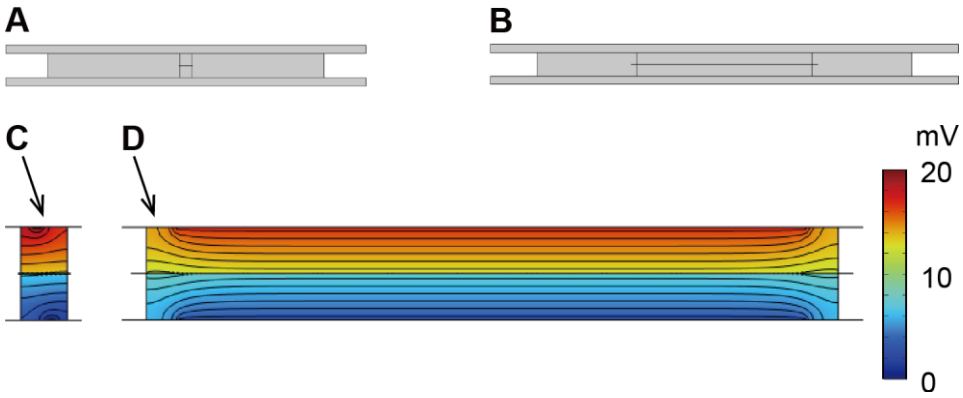


Supplementary Figure 2. Time course of averaged TEER during the process of maturation of RPTEC monolayers, measured with ERS-2 and PT-MPS. A. TEER for Transwell inserts was measured with ERS-2. N = 3 devices. B. TEER for PT-MPS was measured using our custom-made setup. N = 3 devices. Curves (dashed lines) were fit to the data using an exponential formula in the form of $A(t) = a + b \times e^{-t/\tau}$, where A represents resistance at $t = \infty$, t is the time, a and b are fitting parameters, and τ is time constant; the stability point is defined as 3τ = 3.4 days for ERS-2 and 7.6 days for PT-MPS, respectively. The red-colored region represents the stable state beyond the stability point.



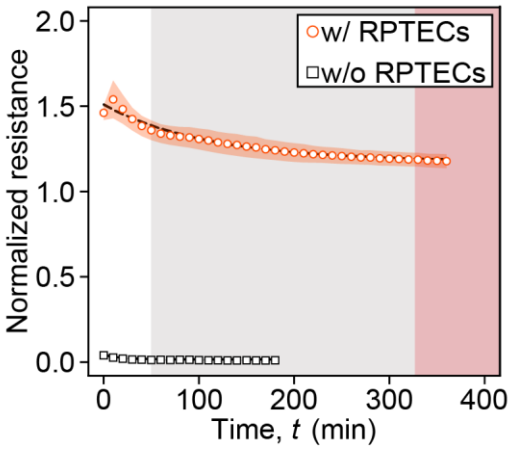
Supplementary Figure 3. Real-time monitoring of impedance upon cisplatin administration on RPTEC monolayers, including the capacitance and TEER curves before the peak values of TEER (curves of colored and filled point) and after the point of increase in capacitance (gray curves). A. Capacitance and TEER of RPTECs treated with 10 μM (N = 3 devices) or 50 μM (N = 4 devices) cisplatin to the apical side. B. Capacitance and TEER of RPTECs treated with 50 μM cisplatin with either co-treatment of 1 mM cimetidine (N = 3 devices) or 10 mM cimetidine (N = 4 devices) to the

basal side. C. Capacitance and TEER of RPTECs treated with 100 μM cisplatin to the apical side (*N* = 7 devices) and basal side (*N* = 3 devices). The capacitance and TEER were normalized to those of the initial values before the drug administration.



Supplementary Figure 4. Simulation of the electrical potential distribution in the channels of the device biased at 20 mV input voltage obtained using COMSOL Multiphysics Ver. 6.1 software. The model was composed of the glass substrates, ITO electrodes, PDMS sheets, the PET porous membrane, and culture medium. The cell culture channel portion between the pair of electrodes through the porous membrane was analyzed without the presence of cells. A. vertical view. B. horizontal view. Simulation results showing the contours of electrical potential distribution in the channels: C. vertical view. D. horizontal view. The model was built in the "Electric Currents (ec)" interface under the AC/DC module using the equations; $\nabla \cdot \boldsymbol{J} = Q_{j,v}$, $\boldsymbol{J} = \sigma \boldsymbol{E} + \boldsymbol{J}_e$ and $\boldsymbol{E} = -\nabla V$, where $\boldsymbol{J}$, $Q_{j,v}$, σ, $\boldsymbol{E}$, $\boldsymbol{J}_e$ and V are current density, charge density, conductivity, electrical field strength, external generated current density and applied potential, respectively. Electrical insulating boundary conditions were enforced on all the boundaries surrounding the culture medium, except the electrodes. As Dirichlet boundary conditions, the boundary condition of the top left electrode (electrode 1) was imposed as voltage terminal and a potential of 20 mV was applied, while zero potential was applied to the bottom right electrode (electrode 4). The electrical conductivity of the culture medium and the porous membrane were set to 1.73 S/m and 1×10^{-17} S/m, respectively. The black lines represent equipotential lines. The color scale from red to blue indicates linear decrement of the electrical

potential.



Supplementary Figure 5. Effect of medium change on resistance with and without RPTECs. Resistance profiles recorded after the medium change in both sides of RPTECs on day 10 (red circle) and in both channels without RPTECs (black square). The resistances were normalized to those of the initial values before the medium change. Curves (dashed lines) were fit to the data using an exponential formula in the form of $A(t) = a + b \times e^{-t/\tau}$, where A represents resistance after stabilization, t is the time, a and b are fitting parameters, and τ is time constant; the stability point is defined as 3τ = 5.4 h with RPTECs and 0.9 h without RPTECs, respectively. The gray and red-colored regions represent the stable state beyond the stability point.

3. Supplementary Movies

Supplementary Movie 1. Real-time monitoring of caspase 3/7 activation in RPTEC monolayer treated with 100 μM cisplatin and CellEvent™Caspase-3/7 to the basal side. Caspase 3/7-positive cell imaging was carried out using a confocal microscopy with the device in a stage top incubator. The interval between images is 2 h and the movie is captures for a total duration of 18 h. Scale bar = 200 μm.

Supplementary Movie 2. Track of detachment cells in caspase 3/7-positive cells in RPTEC monolayer treated with 100 μM cisplatin and CellEvent™Caspase-3/7 to the basal side. Magenta circles and

colored line represent the caspase 3/7-positive cells and the tracks of the detachment cells, respectively. The interval between images is 2 h and the movie is captures for a total duration of 18 h. Scale bar = 200 μm.